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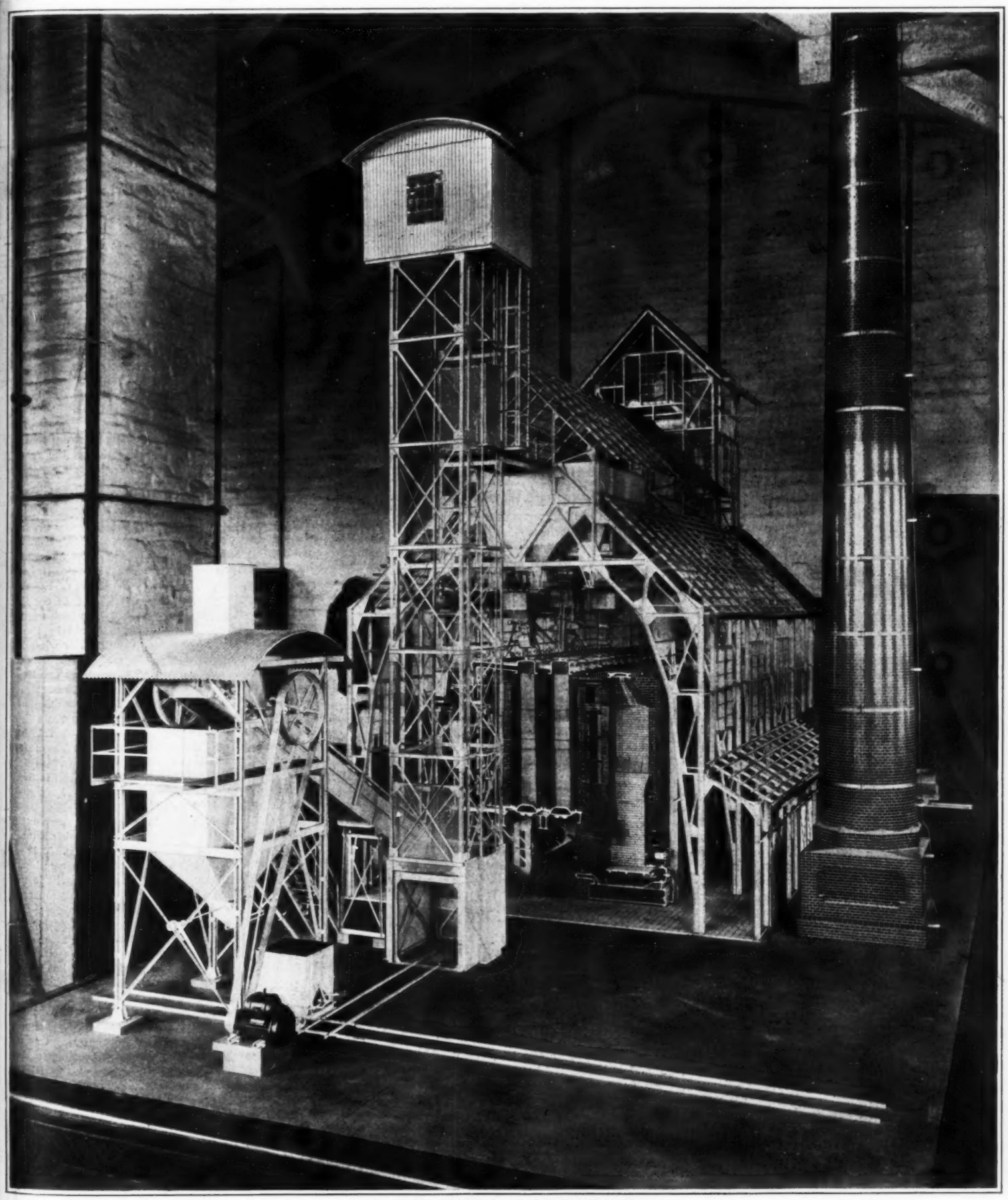


One of the Exhibits in the Munich Museum.

A COMPLETE MODEL OF A GAS WORKS FURNACE HOUSE.—[See page 389].

Experimental Evidence Concerning the Structure of the Atom*

By Albert W. Hull, Ph.D., Instructor in Physics, W. P. I.

THERE is a great deal of scepticism in the world today regarding the reality of electrons, and it is due, I am sure, to unfamiliarity. Everybody believes in atoms, which they have neither seen nor perceived by any of the senses. And they have good reason to do so.

There is better evidence of the existence and identity of the electron than of that of any known atom. For example, what is the mass of an atom? It was not known within 500 per cent until last year, when the mass of the electron was accurately determined by Prof. Millikan, at Chicago, and it is known that the mass of the hydrogen atom is 1770 times that of the electron.

An electron is a very small body, having a charge of 4.89×10^{-10} electro-static units of electricity and a mass of 9.2×10^{-28} grammes, which is 1/1770 of the mass of a hydrogen atom. There is good evidence that it is made of pure electricity, but there is no harm in thinking of it, for the present, as ordinary matter, whatever that is.

Electrons are present in large numbers in all known substances, and can be very easily obtained from them. Most of the so-called radio-active substances are continually shooting them out with velocities nearly as great as that of light. When these rapidly moving electrons were first discovered, before their identity was known, they were given the name of β rays, and they still retain that name, though they differ in no respect, except velocity, from other electrons. Other bodies can easily be made to give up electrons. For example, any body heated to red heat or above emits large quantities of them. There is a continuous stream of electrons flying across the spaces between the filaments of an incandescent lamp, and if an extra wire were sealed into the bulb these electrons could be easily caught and measured. The current of electrons from such a filament at a very high temperature may amount to several amperes from each square inch of surface. Finally, any substance will give out electrons if X-rays fall upon it, or rays from any of the radio-active substances, or ordinary light of short wave-length, especially the very short, invisible rays known as ultra-violet.

These electrons can easily be observed. If they are moving very fast, they cause fluorescence on the bodies where they strike, like the familiar green of the X-ray bulb. If moving slowly, their presence can easily be detected by the charge they carry. They can be accelerated, retarded, or deflected in any desired direction by both electric and magnetic forces, and their charge and mass easily measured. And it has been found that the electrons obtained from all substances, ranging from hydrogen to platinum, and by whatever means they are obtained, have precisely the same charge and mass. In other words, there is but one kind of electron.

All bodies, therefore, contain electrons. How many, and what are they doing? Are there many millions, peacefully reposing, or very few, in violent agitation?

The answers to these questions can be briefly stated. There are in conductors some electrons, probably about one for each atom, which can move freely from one atom to another, and constitute the ordinary electric currents. There are other electrons, those in non-conductors—and we shall see that there are also some in conductors—which are resident in the atoms, bound there by definite forces that are characteristic of each substance. The phenomena of optics show that the number of these bound electrons in each atom must be proportional to the atomic weight, and a very small multiple of it; that is, a hydrogen atom contains a very small number of electrons, probably not more than a dozen, while a platinum atom would contain 200 times as many. Beyond this very little is known about these electrons, and the purpose of the following experiments was to obtain evidence about them.

These experiments were made upon electrons produced by ultra-violet light, and before describing them I shall explain what light is. A light wave is a wave of rapidly oscillating electric and magnetic force. By electric force I mean a force that will act upon a charged body, such as an electron, if there is any there, and by an oscillating electric force I mean one that reverses its direction very rapidly, so that if at any instant the electron is acted on by a force from left to right, a very small fraction of a second later it will be acted on by a force from right to left. The number of times that the electric force reverses its direction in one second is called the frequency of the light. You are more familiar with wave-length which is the distance light travels while the electric force is changing its direction once. Since light travels 186,000 miles in one second, and the average wave-length is 1/50000 of an inch, the electric force must oscillate 10^{15} times per second, i. e., the frequency of ordinary light is 10^{15}.

Consider how such a light wave can tear an electron from an atom. The most natural way that suggests itself is that the electron is dragged by the electric force, first in one direction and then in the opposite, and that when the force is great enough it may be dragged clear out of the atom before the force reverses. But if this were true, the velocity with which the electron flies off would be greater the greater the electric force, i. e., the more intense the light; and this has been tried and found not to be the case. Also a very simple calculation will show that this could not be expected to be the case. The electric force in the light wave can easily be calculated, and is millions of times too small to give to an electron the velocity which it

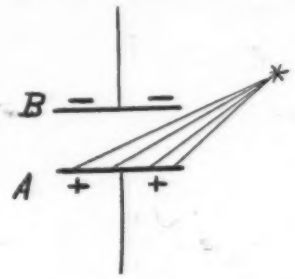


Fig. 1.

has when it leaves the atom, to say nothing of dragging it out of the atom.

We have to consider, therefore, the case of a very small electric force producing a very large effect, and there are only two ways known in which such an action takes place. The first is that of the small trigger which releases the powerful discharge of a gun; the second is that of the small timed blow, which gradually sets a body into greater and greater vibration, like the dog trotting across a bridge, or the sound wave from the voice that sets the organ pipe or piano string into resonant vibration, and is reputed to have caused the fall of the walls of Jericho.

Both of these methods appear possible. We know that atoms, like the powder in the gun, contain large stores of energy, and it is easy to believe that the force in the light wave might cause an atom to explode. But the velocity of the bullet does not depend in any way upon the size or kind of the trigger, and hence we should expect the velocity with which the electron is shot out to be independent both of the intensity of the light, as was found to be the case, and also of the *kind* of light, that is, its frequency. The velocity of electrons shot out by light of different frequencies should be the same.

If, on the other hand, there is in the atom an electron whose natural frequency of vibration is the same as

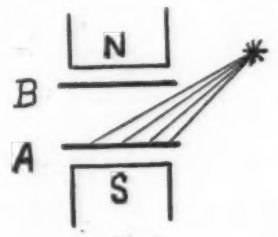


Fig. 2.

that of the light, then the electric force in the light wave might act upon it in exactly the same way as the mechanical force in the sound wave acts on the piano string, and gradually increase the amplitude of its vibration until it finally, in one of its oscillations, passes beyond the reach of the forces that held it in the atom, and escapes. The velocity which it has after escaping would bear some relation to the frequency with which it was vibrating, and this must be exactly the same as that of the light. Now if light of a different frequency fell upon this electron it would have no effect, because the electron would not be in tune with it. But if there were in the atom a second electron, which could vibrate with this second frequency, it would be set free, and its velocity after escape would depend on its own natural frequency, and would probably be different from the velocity of the first.

This gives a method of deciding between the two possible theories. If the light causes the atom to explode, then the electrons produced by light of different frequencies should have the same velocity; if the light sets the electron into resonant vibration, the electrons produced by light of different frequencies should have different velocities.

The purpose of my experiments was to decide between these two theories by measuring the velocities of the electrons as they were shot out from a metal plate on which light of very short wave-length was falling.

The velocity of these electrons is, roughly, 2,000,000 feet per second. It is therefore impractical to try to measure the time of their flight between two fixed points, although this has been done. But there are many other ways of measuring their velocity. Just as the velocity of a bullet can be measured by the amount it is deflected downward by the force of gravitation in going a fixed distance, or by the distance it can travel against a given force, such as the resistance of a pine plank, before being brought to rest, so the velocity of an electron can be measured, either by the amount it is deflected by a given electric or magnetic force, or by the distance it can travel against such forces before being brought to rest.

I chose the latter method. Ultra-violet light fell upon a metal plate A, carefully insulated, in a vacuum, and caused it to shoot out electrons toward a parallel plate B, also carefully insulated. If B were uncharged, all the electrons shot out by A could reach it, and the charge carried by them, and hence their number could be measured by an electrometer connected to B. But if B were charged negatively, it would repel the electrons, and when this repulsion became strong enough the electrons would be brought to rest before they reached B and driven back to A.

Hence, as the negative charge on B was increased, fewer and fewer electrons reached B, and finally none at all. When this stage was reached the repulsion of B must have been just sufficient to stop the fastest of the electrons shot out by A, and from the potential to which B had to be charged to produce this effect the velocity of these electrons could be calculated.

The velocities were determined in this way for electrons produced by light of different wave-lengths, and it was found that the shorter the wave-length of the light, the greater the velocity of the electrons produced by it, and, further, that there was an exact proportionality between the wave-length of the light and the velocity of the electrons it produced. The velocities were inversely proportional to the wave-length of the light, i. e., *directly* proportional to the frequency of the light.

This shows that the explosion theory, which requires that the velocity of the electrons shot out by the exploding atoms should be the same, no matter what kind of light caused the explosion, cannot be correct. The resonance theory, on the other hand, agrees excellently with the results of these experiments. The fact that the velocity of the escaping electrons is proportional to the frequency of the light which produces them is exactly what we should expect, if the small electric force in the light wave, being exactly tuned to the natural frequency of vibration of the electrons, causes it to vibrate with larger and larger amplitude, until it finally escapes. We have, therefore, good evidence, not proof, of the correctness of this theory.

In order to test this theory further some new experiments have been recently made, which furnish some interesting and somewhat unexpected evidence. It is well known that a magnet can be divided into small parts without limit, and each part will still be a little magnet. This shows that magnetism must be a property of very fine particles of the substance, probably the molecules themselves. Many years ago the great Maxwell pointed out that these molecules would behave in this way if each molecule contained an electric circuit, in the form of a ring around its center, in which an electric current could flow without resistance. The molecule would then be a little electro-magnet, with a north pole opposite one face of the ring and a south pole opposite the other, and when acted upon by magnetic force would turn so that the plane of the ring was perpendicular to the direction of the force, thus making its poles parallel to the force. Maxwell showed that this theory could account for the magnetic behavior not only of iron, but of weakly magnetic bodies also, which no other theory would do.

No one but a Maxwell would have been bold enough to suggest such a theory, which seemed quite unbelievable at that time. But it has recently been proved in this Institute, by the beautiful experiments of Prof. Duff and Prof. Olshausen, that a stream of electrons produces exactly the same effect as an electric current

* A paper read before the W. P. I., Chapter of the Society of the Sigma Xi, April 23rd, 1912, published in the *Journal* of the Worcester Polytechnic Institute.

in a wire. Hence, if those electrons, which are made to vibrate so violently when ultra-violet light strikes them, are really rotating all the time about some center in the atom, like the planets in the solar system, they will produce precisely the same effect as the little currents which Maxwell imagined. They will make the molecule a little magnet, and when this molecule is placed in a magnetic field it will swing around so that the line joining its poles is parallel to the direction of the magnetic force, and that will make the plane of the orbit of the electrons perpendicular to the direction of the force.

Suppose, now, we place our plates *A* and *B* between the poles *N-S* of the magnet, so that their planes are perpendicular to the line *N-S* joining the poles of the magnet. The magnetic force is in the direction *N-S*, hence the molecules in *A* will swing around so that their poles are in the line *N-S*, and the planes in which the electrons are vibrating will be perpendicular to *N-S*, and, therefore, parallel to the surface of the plate *A*. When the light strikes them and increases the amplitude of their vibration, the direction in which they are shot off must, if our theory is correct, be tangent to the circle in which they were revolving, and that is parallel to the surface of the plate. Hence if there is a film of gas on the surface of the plate, as we know there is, they will go plowing along under this film and very few will escape. When the magnet is taken away, the orbits of the electrons will again assume their random direction, and many of the electrons will be shot out perpendicular to the plate.

The current of electrons from *A* to *B* should therefore be very much smaller when the magnet is present than when it is away, if our theory is correct, and this offers a means of testing the theory.

The object of my experiments is to measure these currents and test the theory. I have already made measurements of a large number of different substances, and the results agree exactly with which I have just predicted. For example, when the plate *A* is of aluminium, the current of electrons between it and the plate *B* is reduced to two per cent by bringing up a weak magnet.

The remarkable fact which I have discovered is that all substances, both the magnetic and the so-called non-magnetic substances, behave in the same way, though to a different extent. For example, if the plate *A* is of bismuth, a very diamagnetic substance, the current from it to plate *B* is reduced to one-half by bringing up this same magnet, instead of 1/50, as in the case of aluminium. This indicates that all bodies are magnetic, that is, their molecules are made little magnets by the electrons revolving in them; there are no *non-magnetic* substances. Why some bodies, like iron and nickel, appear so very much more magnetic than other bodies, whether because they contain more of these revolving electrons, or because some of the electrons in these bodies are revolving with greater velocity, is a question about which I hope to obtain some evidence from further experiments.

Blast Furnace Slag and Its Applications*

An Important By-Product of the Iron Industry

BLAST furnace slag is a by-product of the iron industry. Pig iron or crude iron is produced by firing, in the blast furnace, a mixture of iron ore, coke or charcoal and other substances, such as limestone, claystone, etc., which vary with the composition of the ore and the character of the desired product. The non-volatile ingredients of these additions combine with the earthy parts of the ore and the ash of the fuel to form a glass-like slag which accumulates, in molten form, in the lower part of the furnace, above the heavier molten iron, and is drawn off separately, from time to time.

Blast furnace slag consists chiefly of silicates of lime and alumina. Its principal ingredients, therefore, are silica, alumina and lime, but it also contains various compounds of other elements. It is produced in vast quantities, for many blast furnaces yield more slag than iron. It is estimated that about 141 million tons of blast furnace slag are produced annually in the entire world, and 30 million tons in Germany alone. Formerly, the slag was simply thrown out on the ground, and large tracts have been covered with it. The slag field of one German mine is larger than the island of Heligoland. The difficulty of reclaiming such land to cultivation led to the earliest attempts to find some useful application for blast furnace slag. Various methods of utilizing slag have been developed, though great quantities are still thrown on the slag fields. The utilization of blast furnace slag is a problem of great economic importance, because of the immense supply of material, and the progress which has been made in this direction is a notable achievement of technical chemistry. In this case, as in others, a worthless and troublesome waste product has acquired great value as the raw material of a new branch of industry.

Many varieties of slag swell and form porous masses resembling pumice stone when they are flooded, in the molten state, with water. This artificial pumice is employed as an insulator, for polishing wood, and for other purposes. A fibrous insulating material, called slag wool or spun slag, is obtained by the action of a blast of steam on the molten slag, containing little lime and sulphur, which is produced when charcoal is the fuel employed in the blast furnace.

Slag is also used as a raw material in glass-making. Many sorts of slag closely resemble common bottle glass in chemical composition and can be converted into workable glass by adding a little silica and alkali. Blast furnace slag, however, contains too much alumina and coloring matter to be convertible into window glass.

Where blast furnaces are situated near coal mines the slag forms a convenient material for filling the voids left by the extraction of the coal, in order to prevent sinking of the ground over the workings. The slag may be used in lumps or in the form of sand, obtained by pouring the fused slag into cold water. This slag sand may be carried, by a powerful stream of water, through pipes into the mine and to the place of deposit. By this method, which is now used in many mines, large voids can be filled in a comparatively short time.

Blast furnace slag is employed also in the production of artificial marble, architectural ornaments and the like.

The uses enumerated above possess only a local and limited importance and absorb but a small portion of the waste product. The applications mentioned below are of greater importance and are capable of utilizing very large quantities of slag.

Those varieties of slag that are not affected by exposure to the weather are useful materials for the construction of roads and dams. For this purpose the molten slag is allowed to cool and solidify, as slowly as possible, into large blocks which, in these conditions, become as hard as basalt. The blocks are used in their original forms, broken and trimmed to form regular paving blocks, or converted into rubble in the stone-crusher.

Building bricks are made from slag by two methods. In the old method, which is used only for the slag of charcoal-burning blast furnaces and is now of little importance, the hot liquid slag is flowed into cast-iron molds, which are then covered with iron plates and allowed to cool slowly under a layer of embers or in special tempering ovens. Slow cooling is essential, for rapid cooling produces in the exterior of the block a tension sufficient to cause subsequent fracture. The liability to fracture can be diminished somewhat by mixing fragments of solid slag, coke or brick with the liquid slag.

The new method of making slag brick uses the slag of coke-burning blast furnaces and is of great importance as most blast furnaces are now operated with coke. The molten slag is first granulated by allowing it to flow into cold water. The grains of slag sand thus produced are several millimeters in diameter, resemble glass and form a hard cement with lime. A mixture of slag sand and milk of lime is pressed into bricks, which at first are soft but become as hard as stone after a few weeks' exposure to the air. The process of hardening may be accelerated and made independent of the weather by heating the bricks with high pressure steam in specially constructed hardening ovens, just as other sand-lime bricks are hardened. There are also patented processes in which the bricks are hardened in an atmosphere of pure or diluted carbon dioxide under pressure. Slag bricks are very porous and are therefore especially suitable for the walls of dwellings. They are as strong as burned clay bricks and their strength increases with age.

The production of hydraulic cements from blast furnace slag has already become a recognized branch of industry which has attained a flourishing condition despite many obstacles. Four very distinct products of this character, known as "blast furnace cement," "iron Portland cement," "Portland cement," and "slag cement" or "Puzzolan cement," are made by different processes. "Blast furnace cement" is made by grinding very rapidly cooled and glassy slag with a small proportion of Portland cement clinkers. Quickly cooled and glassy slag, if of suitable chemical composition, possesses the property of hardening under water in presence of lime or substances which yield lime. This property is utilized, as we have mentioned, in the production of slag brick. Slowly cooled slag is not glassy and does not possess this property. Even glassy slag will not "set" or consolidate alone. It requires the presence of a substance capable of starting the process of consolidation. Such a substance is the lime which is set free from Portland cement by the action of water. In "blast furnace cement," therefore, the consolidation is effected mainly by the glassy slag, the small proportion of Portland cement serving merely to start the process. Hence this variety of cement differs essentially from the other three varieties, which contain smaller proportions of slag. In making "blast furnace cement" very rapid and energetic cooling of the slag is of the utmost importance. The hot liquid slag can be quickly converted into hard glassy sand either by letting it flow into cold water (Langen's method) or by atomizing it by a blast of air or steam (Passow's method). The water cooling process is generally employed.

"Portland cement" is made by the ordinary Portland cement process, quickly cooled slag being substituted for natural marl. The slag is ground with limestone, the mixture is burned and the resulting clinkers are again ground.

"Iron Portland cement" is a mixture of 70 parts of the slag "Portland cement" described above with 30 parts of granulated glassy slag.

The varieties called "slag cements" or "Puzzolan cements" are mixtures of finely ground glassy slag and lime.

In all of these processes the chemical composition of the slag is of prime importance. In current practice, only basic slags, containing much lime, are employed.

As a filler for concrete slag which has cooled slowly or has been disintegrated by exposure to the atmosphere is chiefly employed. Even slag of this character takes part in the hardening process in these circumstances and slag concrete grows stronger with age. Slag granulated by water-cooling is less suitable for concrete. It was formerly thought that the sulphur contained in slag might corrode iron used for reinforcement, but not a trace of rust has been found on iron parts imbedded in slag concrete for many years. The objection to the use of slag, even in reinforced concrete, therefore, is entirely groundless.

* Condensed from an article by Hans Fleissnern in *Die Umschau*.

Life Phenomena Obeying the Laws of Chemical Action

IT is recognized that heat is an accelerator of chemical reaction, which takes place more rapidly as the temperature rises. On the other hand, biologists show that in the case of living animals there are diverse reactions which follow the same law, such actions taking place more rapidly at a higher temperature, this of course within the limits which are favorable to life. As to chemical action it is found that a rise of 10 deg. Cent. will double or triple the speed of the chemical reaction, or in other words the coefficient or factor representing such increase is at least 2 for 10 degrees rise. But for physical reactions this factor is much lower, so that there is here an excellent method for judging whether any given effect shown by a living being is of a physical or a chemical nature. Physiologists have already made some interesting applications of this idea. Thus Snyder and Maxwell found that heart beats and nerve conductibility are based on chemical and not on physical effects. Loeb observed the parthenogenetic development of sea-urchins' eggs in this way. Some actions of the liquids on eggs were accelerated by a rise in temperature and the coefficient of increase was greater than 2, indicating a chemical effect. For a long time past, embryologists who followed the development of frogs' eggs noticed that some of these phenomena depended on the temperature. Hertwig finds that the development requires 6 days at 20 deg. Cent., 10 days at 15 degrees and 21 days at 10 degrees. According to Peter, a rise of 10 degrees increases the rate of development of the *Sphaerechinus* 2.15 times, and the *Rana* 2.86 times, so that these cases may be reckoned among chemical actions. Recent work of Szymanski shows that this law also holds good for the movements of animals. Observations were made upon the ant, *Formica rufa*, coming to the nest or leaving it. He measures in seconds the time needed for the ant to cover a distance of 4 inches. At 11.8 deg. Cent. this distance is covered in 4.19 seconds, and at 20 degrees, 1.60 seconds. He finds the coefficient to be about 3, so that here also we have a case of chemical reaction. Przibram comes to the same conclusion in his observations on various insects.

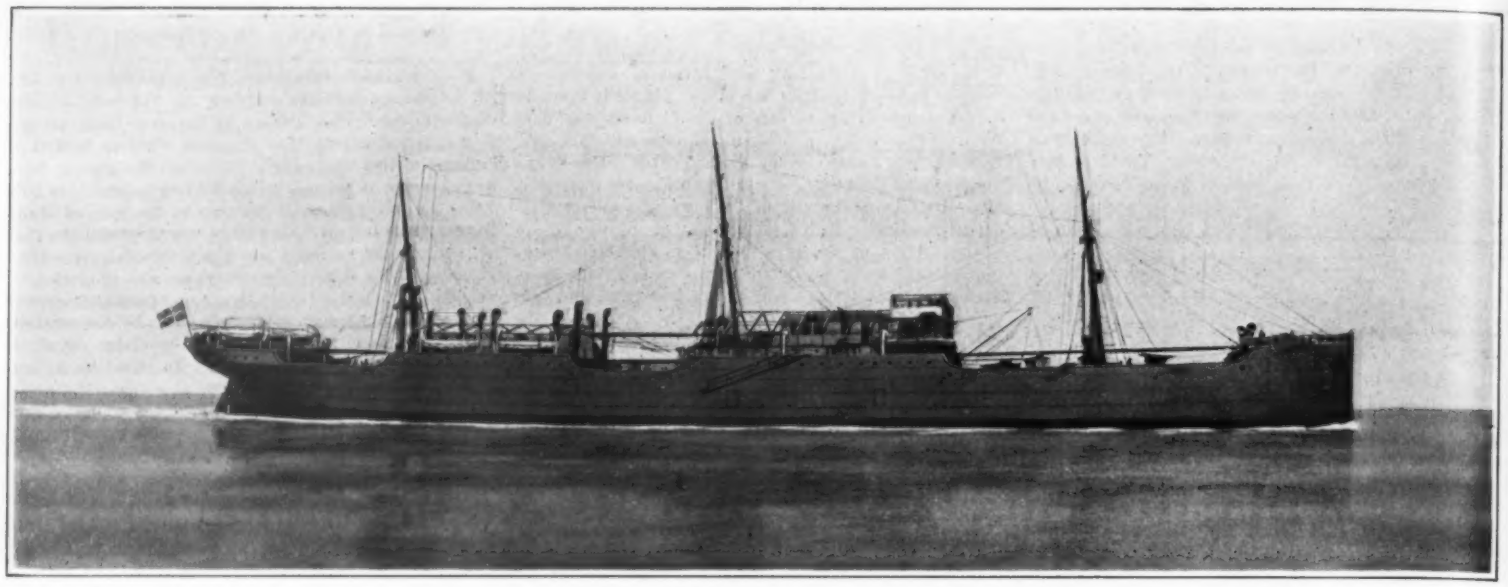


Fig. 1.—The Danish Vessel "Selandia." A Diesel Engine Ship.

The "Selandia"

A Danish Oil Engine-Driven Vessel

THE accompanying illustrations show the general design of a most interesting oil-driven vessel, the electrical illumination of the cabin, and the details of construction of the propelling machinery. For the photographs and data of the Diesel engines in the "Selandia" the writer of this article is indebted to the Aktieselskabet Burmeister and Wains of Copenhagen, Denmark.

Fig. 2.—One of the Parlors, with Artistic Illumination.

As will be seen from photograph (Fig. 1) the motorship "Selandia" is constructed as an awning deck ship having a length between perpendiculars of 370 feet and a breadth of 53 feet with a depth to upper deck of 30 feet.

The carrying capacity is about 7,400 tons and the calculated speed at sea with full cargo is about 12 knots. The cabins are beautifully illuminated with electric lights in ceiling panels and in side wall brackets as shown in the accompanying illustration (Fig. 2).

There are auxiliary motors of 250 indicated horsepower, each having a speed of 230 revolutions per minute, each furnished with a dynamo and an air compressor. The latter is calculated to supply air under a pressure of 20 atmospheres, which is used for reversing the main motors, and also for furnishing the air compressors of the main engine with air for injection.

The current taken from the dynamo, which is placed on the same shaft with the compressor, is not only used for lighting but also for working the different auxiliary devices such as winches, pumps and refrigerating machines. There are two auxiliary motors in order to have always one in reserve.

As seen in illustrations (Fig. 3 and Fig. 4) the propelling machinery in the ship consists of two main Diesel motors, each of 1,250 indicated horse-power, and two auxiliary Diesel motors, each of 250 indicated horse-power. The main motors are eight-cylinder Diesel engines, working on the four-stroke system. The number of revolutions at normal speed is 140 per minute and the reversing takes place by means of compressed air, the shaft from which the valves are moved being so arranged that it can be displaced lengthwise after *all* the rods which lift the valves have been removed from the shaft by means of a crank motion. The reversing from full speed ahead to full speed astern can be executed in less than 20 seconds.

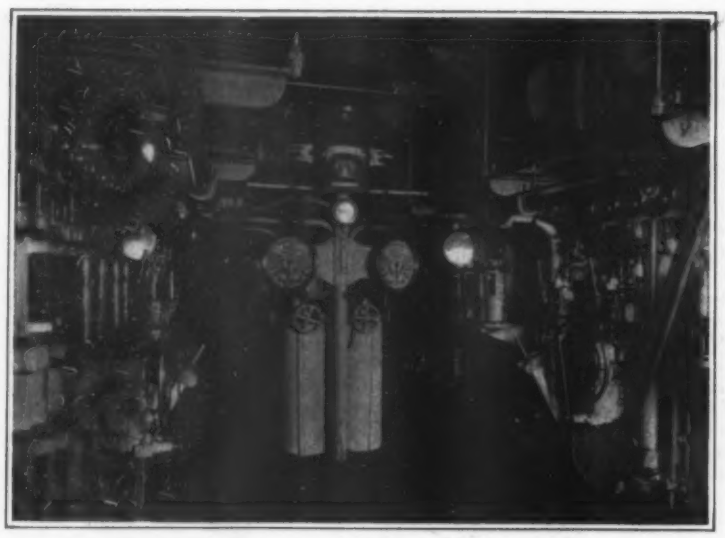


Fig. 3.—Upper Gallery in the Engine Room.

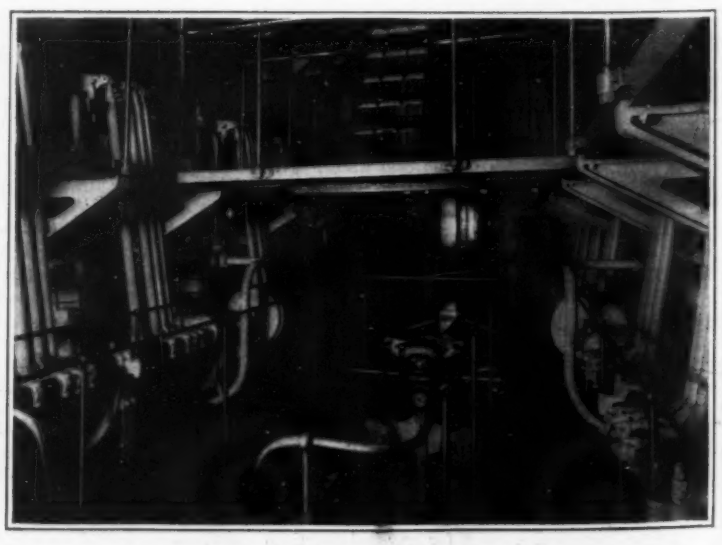


Fig. 4.—Lower Deck of the Engine Room.

The work of the engine at sea is regulated by an Aspinall's governor, which, on any sudden rise of the number of revolutions beyond the normal, immediately shuts off the supply of fuel oil, and only opens again when the revolutions have dropped down to a certain predetermined number. As the engine has eight cylinders, and the filling at the start is about 0.6, the engine can always be started at any position whatever. On the shaft is a little flywheel, only 2 meters in diameter.

This is provided with toothed worm wheel gearing in the periphery, which drives a worm, so that by means of an electric motor the main engine can always be turned. There is an air compressor on each main engine for compressing air from 20 atmospheres up to 60 atmospheres pressure to inject fuel oil into the cylinders. These compressors are so arranged that they can be adjusted for half or complete filling. Half filling is used when both of the pumps are working at each engine. In case one of them should be damaged the remaining pumps will be put on complete filling and will give sufficient air for injection of the fuel oil for both of the main engines.

As a reserve for the preliminary compression to 20 atmospheres matters are so arranged that the exhaust valve at one of the cylinders of the main engine can be removed and replaced by a delivery valve, so that the cylinder will be brought to work as a compressor, which compresses the air to 20 atmospheres. In that case the motor only works with 7 cylinders, but trials have proved that the reversing and working nevertheless is performed in a most satisfactory manner.

The auxiliary machinery includes two sets of electrically-driven lubricating-pumps, circuit pumps, cold and hot water sanitary pumps, and bilge pumps, two motor transformers, one refrigerating machine, one donkey boiler for heating and steam extinguishing in the holds and also for working of a steam-driven compressor, which can compress the air to 60 atmospheres.

The electrically-driven lubricating pumps pump the oil each from its own tank, which is placed in the bottom of the ship, through the main gearings, from there through the crank-shaft, connecting rod brasses, through the hollow-cored connecting-rod to the cross-head brasses, from there through the piston-rod to the top of the oil-cooled piston, back through the piston-rod and from there ejected over the guide.

The cooling of the oil takes place on the guide-faces as these are cooled. Further cooling can be executed by pumping oil through an oil cooler formed as a surface condenser. From the two compressors of the auxiliary-motors, which are carried out as triple-compressors, pipes are led from the intermediate cooler with an air pressure of about 8 atmospheres to the siren, which is fitted on the mast.

There are two settling tanks arranged in the top of the casing to which fuel-oil can be pumped from an air-driven pump in the engine room; each tank is of such dimensions, that it contains sufficient oil for 12 hours' normal work. The purpose of these tanks is to have the water separated from the oil here so that comparatively clean oil will be led to the motors.

All winches are electrically-driven and the same is true of the windlass and the steering engine. The large and bright cabins and rooms of the ship are of exceptional size and each is fitted out with folding bed, a spacious wash stand, writing table and chairs.

There are a large number of double cabins for two passengers each and single cabins for one passenger. There is also a large elegant dining-saloon as well as ladies' saloons. They rise above the deck and are thus well lighted and airy. The space on the aft end of the dining saloon forms a hall, and a finely finished staircase gives access to the rooms above, where is found an elegant smoking-saloon and some special combined sleeping-room sitting-rooms; in front of these rooms is the captain's cabin and chartroom. It need hardly be added that there is a complete wireless telegraph equipment on board.

Model of a Furnace House

AMONG the exhibits at the German Museum in Munich there is a very interesting model of a furnace house in the gas works of Munich, of which our illustrations (see the frontispiece) show two views. The model is built on a scale of one-twentieth of the actual dimensions.

The furnace has a capacity of 32 furnaces with 9 retorts, each measuring 5 meters in length and inclined at 32 degrees. The furnaces are built on the Didier system and have a capacity of 13,400 cubic feet per 24 hours. The entire plant has, therefore, a daily output of 4,240,000 cubic feet.

When the furnaces are working at their full capacity the coal consumption for 24 hours is 880,000 pounds. The handling of this immense amount of coal is effected entirely by mechanical means. The coal is carried from the bins into the furnace house by the aid of bucket chain conveyors. A number of such conveyors raise the coal to vertical shafts between the individual blocks of furnaces. At the top of these shafts the bucket chains discharge the coal into chutes. From this it falls upon horizontal belt conveyors, which then feed the material into bunkers arranged along the sides of the furnaces. The total capacity of the bunkers is 1,100,000 pounds. From the bunkers the coal is lead down into lowries, which feed directly into the retorts. The inclination of the retorts corresponds to the natural angle or rest of the coal, which therefore distributes itself for the entire length of the retort. When the coal is completely coked, the mouth pieces on the discharge side are opened and the coke then slides into a chute, upon which it is slaked with water to be then transported to the yard. For carrying off the steam formed in the baking, steel stacks are provided.

The plant for conveying the coal and coke is actuated by electric motors. A number of staircases, platforms and the like are distributed over the building in such a way as to render every portion of it thoroughly accessible and safe for the workmen.

The entire building is constructed of steel framework and faced with one half thickness of brick. A large number of windows provides proper illumination. The furnace gases are thrown off by four stacks, 130 feet high.

A Resisting Medium in Space

F. W. HENKEL, writing in the *Journal* of the British Astronomical Association, says: "One or two comets besides Encke's have been suspected of showing signs of the effect of resistance, but the evidence is of a somewhat indefinite and contradictory character. I do not know whether one may venture to attribute the outstanding discrepancy of two days between the predicted and observed times of return to perihelion of Halley's comet to a *retarding* effect of the resisting medium upon this *retrograde* comet, just as the *direct* moving comet of Encke is *accelerated*, but, perhaps, the difference of two days is too great to be thus accounted for. Halley's comet, however, moves over so extended an orbit that it is not, perhaps, unreasonable to expect a greater quantitative effect on its motion, though taking into account the difference in their periodic times, 3½ years and 76 years, there is not so much difference after all. But I believe the earlier returns show no such difference between predicted and recorded dates of perihelion passage of Halley's comet, so it is, perhaps, rather rash to generalize upon a single occurrence. The extinction of light in the celestial spaces, due either to the imperfect transparency of the ether or to the presence of cosmical dust and also of *dark bodies*, has been considered by Prof. Turner, Dr. Seeliger, Prof. Kapteyn, and others, while Prof. See has drawn attention to the probable effect of such material upon the aggregation of the Milky Way into clusters and the condensation of these latter into more or less globular form. Though these matters can only be mentioned here, yet on their further consideration will depend much of the future progress of our science in the interpretation of the wonders of the heavens."

Model of Gas Works Furnace House in the Munich Museum.

The United States Patent System—II*

By Robert N. Kenyon

Concluded from Supplement No. 1902, page 384

THE SUBSTANTIVE LAW OF PATENTS.

THE substantive law of patents in this country, by which I mean that part of the law which defines the rights and remedies of inventors and patentees, as distinguished from the method of their enforcement, is in most respect satisfactory and indeed admirable. In its present form it is the result of many years of experience and growth and it is unquestionably the best and most satisfactory system of patent law in the world. In one respect, however, it seems to me to be lamentably deficient or ineffective, and that is in the remedy which it provided for a patentee when his patent has been sustained by the court and a decree given against an infringer.

Section 4919 of the Revised Statutes provides that damages for the infringement of any patent may be recovered in an action at law, and that the court may in its discretion increase the amount found by the jury as the actual damages to a sum not exceeding three times that amount.

Section 4922 provides that in a suit in equity, where a decree is rendered for the complainant, the court may award to the complainant the damages which the complainant has suffered in addition to the profits which the defendant has made and the damages may be trebled in the discretion of the court.

On its face this law would seem to be sufficient, but the courts have construed it to mean or to require that the complainant in an equity suit must show by evidence which amounts practically to a mathematical demonstration the exact part or fraction of the defendant's entire profit or the complainant's entire damage which is due to the use of the infringing device or feature, as distinguished from the part of the damage or profit which is due to other things which the defendant has done or used in connection with the infringing part or feature. This construction or application of the law has made it possible in most cases for the complainant to obtain any recovery at all, although it was apparent that complainant had been greatly damaged and defendant greatly profited. A defendant rarely makes a device which contains nothing but the invention in question. The patented device or feature is almost always associated with unpatented parts or features, and yet the damage or the profit is single or unitary and there is no possible way of determining by a definite mathematical calculation how much of this profit or damage is due to the patented and how much to the unpatented parts.

A striking example of the impossibility and injustice of this mathematical rule is found in the decisions of the courts in relation to the design patents. In the case of *Dobson v. Hartford Carpet Company*, 114 U. S., 440, suit was brought upon a patent for a carpet design. The lower court awarded to the complainant as damages an amount equal to the profit it would have made had the carpet in question been sold by it instead of by the defendant. The Supreme Court reversed the lower court, and awarded nominal damages only, holding that the burden was on the complainant of showing what part of its profit was due to the design alone as distinguished from the part due to the carding, spinning, dyeing, and weaving. Such a division of the profit was manifestly impossible. This decision deprived the owners of design patents in all but exceptional cases of any right of money recovery. The injustice of this rule was so palpable that Congress shortly thereafter passed a law providing for a minimum recovery of $250 in suits on design patents.

But the difficulty of the rule is almost equally great in the case of many mechanical patents. Suppose a patent is for an improvement in an old machine, or device, consisting in adding some new element thereto. The defendant sells or uses the machine as patented and makes a large profit. How much is due to the new element? How much profit would he have made, if he had sold or used merely the old machine? Who can say? How can such a matter be proved with mathematical certainty? In most cases such proof is impossible, and for this reason in most cases there is no substantial recovery.

Or suppose that an infringer has taken the patented device and added some improvement of his own, of more or less value. How can his profit be apportioned between the two? In the case of *Westinghouse Company v. Wagner Company*, 173 Fed. Rep., 361, the patentee had made a valuable improvement in electrical transformers. The defendant company used the patented transformer, adding a new feature thereto, and sold $874,000 worth of the infringing devices. The master found that the defendant's profit amounted to about $134,000 and awarded this sum to complainant. The lower court reversed this ruling on the ground that the complainant had not performed the impossible task of proving how much of this profit was due to the complainant's invention and how much to the defendant's improvement, and the Court of Appeals for the Eighth Circuit affirmed this decree. This may be law, but obviously it is not justice. Under this ruling all an infringer has to do to secure himself against a recovery of profits is to add something of his own to the complainant's device, a thing which can be easily done in almost any case.

An examination of all the decisions in patent causes reported in the Supreme Court Reports and the *Federal Reporter* for the ten years and ten months from January 1st, 1901, to November 1st, 1911, shows that recoveries were awarded in only twenty-two cases out of the many hundreds that have been decided favorably to the patentees in these years. The total recovery in all these cases amounted to about $190,000, a truly pitiful and ridiculous showing, when we consider the enormous value of the patents involved, and the immense profits which have undoubtedly been realized by their infringers.

The law should be amended to provide that a complainant may prove any facts and circumstances tending to show the value to the defendant of the patented device or improvement, or the loss sustained by the complainant, and that the defendant may answer the same, and that the court or the jury may award to the complainant or plaintiff such sum as it may deem just in view of all such facts and circumstances. This would make the law of recoveries in patent causes conform more nearly to the law of recoveries in other cases of tort, and would remedy a great injustice.

Such a provision is found in the Copyright Law enacted in 1909. That law provides in Section 25 that the complainant may recover his actual damages, as well as the defendant's profits, "or in lieu of actual damages and profits such damages as to the court shall appear to be just." The Copyright Law provides further in the same section for minimum and maximum amounts which the court may allow as damages in its discretion; the maximum allowance being $5,000, except in the case of a newspaper reproduction of a copyright photograph, where the maximum is $250. The complainant may prove his actual damages or defendant's profits, if he chooses to do so, but if he does not do so, the court may award such damages as may appear to be just upon all the facts and circumstances proven within the limits specified. This law also provides that "in proving profits the plaintiff shall be required to prove sales only, and the defendant shall be required to prove every element of cost which he claims." This is in marked contrast with the illiberality of the Patent Law, where the burden of proving defendant's cost is thrown upon the complainant.

In the Trade-mark Law enacted in 1905, it is provided in Section 19 that "the complainant shall be entitled to recover, in addition to the profits to be accounted for by the defendant, the damages complainant has sustained" by the infringement, and further, as in the Copyright Law, that "in assessing profits the plaintiff shall be required to prove defendant's sales only; defendant must prove all elements of cost which are claimed."

It is interesting to note in this connection that in Germany, as I am informed, a person who knowingly or through gross negligence infringes a patent, is punishable by a fine not exceeding 5,000 marks or by imprisonment not exceeding one year. In lieu of damages, the court may award to the plaintiff a sum not exceeding 10,000 marks.

PROCEDURE IN PATENT OFFICE.

I shall not discuss at length the procedure in the Patent Office, but shall merely refer to a few features of the present practice of organization which, in my judgment, should be changed.

The number of appeals in the Patent Office should be reduced. At present when an application has been rejected by the Primary Examiner on the merits, an appeal can be taken to a board consisting of three examiners-in-chief; if the decision of the board is adverse, an appeal can be taken to the Commissioner, and from his decision, if adverse, an appeal lies to the Court of Appeals of the District of Columbia, making three appeals in all. There is no justification for so many appeals.

Nor is this all. If an applicant has been defeated in all these tribunals, he may, under the provisions of Section 4915 of the Revised Statutes, file a bill in equity in a federal court, and may bring in adverse parties and the Commissioner, and take testimony to show he is entitled to the patent. If the court decides in his favor, the Commissioner must issue the patent unless an appeal is taken to the United States Court of Appeals. In case the decision is affirmed on appeal, the patent must be issued. This in effect gives two additional appeals, making five in all.

In *ex parte* applications, the appeal to the Court of Appeals of the District of Columbia should be abolished. The Commissioner's decision should be final. If the applicant desires to contest the matter further, he can then file his bill in equity and testimony can be taken and the court can decide upon the evidence. The applicant's rights are fully secured in this way. It is a mistake, in my judgment, to allow an appeal in such cases to a court composed of lawyers without technical training, and to compel them to decide different technical questions without the assistance of any evidence whatever.

In interferences, where the question is simply whether one party or another made the invention first, and where evidence is taken in the usual way, an appeal to the court on this single question of priority is a reasonable procedure; but one appeal should be eliminated. There should be an appeal from the decision of the Board in interferences directly to the court, and the appeal to the Commissioner in such cases should be abolished.

The present practice in interferences has become so complicated that the delays and expense resulting therefrom are almost intolerable. Years are sometimes consumed before these interferences are finally determined, and then the struggle is merely transferred to the courts to be fought all over again. The variety of motions and petitions that an ingenious attorney can devise, for purposes legitimate or otherwise, is certainly astonishing and distressing to one who desires a prompt decision of his rights. This practice should be simplified and made to conform more nearly to the practice of a court of equity.

As an illustration I shall cite one point in which such simplification might be secured.

Under the present procedure, when an interference is declared, the Examiner of Interferences takes jurisdiction of the case. A motion to dissolve may then be made by either party upon a variety of grounds specified in Rule 122. Such motions, if in proper form, are sent to the Primary Examiner for determination, and from his decision an appeal may be taken in certain cases to the board, and in other cases directly to the Commissioner. If the motion to dissolve is finally denied, the case goes back to the Examiner of Interferences again. A year or more may be consumed in this manner before the trial of the case really begins before the Examiner of Interferences. This should be changed. When an interference is once declared, and the Examiner of Interferences acquires jurisdiction, he should retain it for all purposes until he has fully disposed of it in one way or another. All motions should be made before him, and decided by him. A motion to dissolve is in effect a demurrer or a motion for judgment on the record. If sustained, the case should be dissolved, or a judgment of priority entered according to the nature of the decision. If the decision is upon the merits holding that a claim is unpatentable or that one of the parties has no right to make the claim, or that the claims have different meanings in the different cases, there should be an appeal to the board to be heard *inter partes*, and if it affirms the decision, there should be a further *inter partes* appeal to the Commissioner. If the Examiner's decision dissolving the interference is not on the merits but is based on the ground that there has been some irregularity in declaring the same, one appeal would certainly be enough and that should be directly to the Commissioner.

If the motion to dissolve is denied by the Examiner of Interferences, or by the board or Commissioner on appeal, the case should proceed before the Examiner of Interferences until finally determined by him upon evidence. From this decision there should be an appeal to the board, and then an appeal from the board to the court. All other motions, such as motions to shift the burden of proof, could be heard by the Examiner of Interferences at the same time. In this way the Examiner of Interferences would have entire control of the case until it was finally disposed of by him. He would have charge of everything that was done in the case and could control it and see that it was diligently prosecuted. Moreover the consideration of the motion to dissolve would acquaint the Examiner of Interferences with the issues involved and in a measure prepare

* Paper read before the American Institute of Chemical Engineers at Washington, December 22, 1911.

him for the further consideration of the case if it is finally decided that the interference must proceed.

In support of the present practice, it is argued that the Primary Examiner is better acquainted with the particular art in question, and, therefore, better qualified to pass on the questions raised by a motion to dissolve. But the Examiner of Interferences has to pass on the question of priority and questions ancillary thereto, if the interference proceeds, and, if he is qualified to do this, he is qualified to decide motions to dissolve. On motions to dissolve, the issues are limited and definite, and their determination does not require a knowledge of the entire art. At any rate the advantages of the proposed method outweigh in my judgment any disadvantage that might flow from any difference in the qualifications of the two tribunals.

In conclusion I again urge the importance of proceeding with reasonable caution in the amendment of the law. Let us have no hesitation in correcting acknowledged defects, but let us be careful to avoid new schemes of improvement so radical in their nature that there is nothing in past experience to afford any reliable means of determining whether they will work for good or for evil.

Scientific Management from a Social Standpoint*

By Ralph E. Flanders

THE author of this paper wishes it to be understood that he is not an authority on "scientific management." His viewpoint is that of an outside observer with an investigating turn of mind. This position of outside observer is often a very advantageous one. An inside view alone gives us no perspective or sense of distance.

To be strictly scientific we should begin with definitions, but it is difficult for an outsider to attempt to define this new movement. In a general way, one might say, however, that the scientific management of a manufacturing concern involves the direct control by the management of every detail, and of every, even the smallest, move of every person employed, and the management of every piece of equipment or apparatus—all in accordance with thoroughly investigated and applied standards—to the end that the profits of the employers and employees alike may be increased to the highest degree possible.

Capable men all through the country are striving to put into actual working form the ideal roughly stated above. They are meeting with a large measure of success in their work, and in their enthusiasm they are making claims that look forward to great social reforms and the permanent betterment of industrial conditions. Among the things hoped for are: the permanent increase of profits and wages; the decrease of unemployment; and the growth in character and intelligence of those now classed under the general term "unskilled labor." These are the claims it is now proposed to investigate.

COMPARISON BETWEEN SCIENTIFIC MANAGEMENT AND LABOR SAVING MACHINERY.

We cannot reason about a thing whose qualities are unknown. The object must be thoroughly studied, and almost invariably when this is carefully done we find that the particular object of our study is in no sense unique, but belongs to some clearly defined class. By studying the past history and the recognized present effects of that class, we can form a clear idea of the future history and the effects of the new object or movement under consideration. This is the way in which we can investigate scientific management. The more we analyze and study its nature the more clearly do we see that it belongs to the class of labor saving machinery. All that labor saving machinery has done for the world, scientific management will do; that which labor saving machinery has failed to do, scientific management will fail to do. It should do as much—it can do no more.

Let us first ask what is the effect of scientific management on the worker. As with any labor-saving machine the effect is that of specialization. In place of broad, general skill and a wide range of activities, the work is confined to a few regulated motions, the necessary information for which is presented to the worker in blueprinted, typewritten or printed form. This complete specialization has aroused opposition of workers everywhere, especially where scientific management has never been tried, or is just about to be tried, or has been only half tried, or has been unwisely and clumsily tried. Where the scheme has been worked out with scientific thoroughness, the workmen have finally received it in a friendly spirit.

The reasons for this are plain: In the first place, the goal should be, and usually is, more work with the same effort; that is, easier work—not harder—but more of it. In the second place, the vast increase of the so-called "non-productive" labor, foremen, clerks, etc., necessitates in the end a change of employment throughout the whole force. The man with brains and experience enough to be a skilled mechanic, and who would object to minute supervision, is too valuable to waste on the mere mechanical machine work. He becomes a functional foreman or a productive specialist of some other kind. The unskilled man is raised from his lowly position to that of a trained machine operator, and the still less experienced man takes his former place as a helper. Of course, there are some skilled and intelligent men—but not many—who are unable to adapt themselves to the change. That has always been the case when new labor saving machines or processes have been introduced. These men may be assisted individually until they have re-adapted themselves, but, since the beginning of things, it has never been possible nor wise to stop the course of improvement for their sake.

When we consider the effect of scientific management on the profits of the employer, the analogy with labor saving machinery is especially striking. This analogy has been fully developed by Mr. Fred J. Miller, of the Union Typewriter Company. A few of his analogies are as follows:

Scientific management, like labor saving machinery, is best adapted to shops manufacturing in large quantities where the separate operations are comparatively simple, or may be made so.

Like the machine, it must be specially and skillfully adapted to the particular work in hand. An adjustable machine, supposed to be adaptable to a wide range of conditions, is likely to prove a failure. The expert designer must construct his machine or system for some particular work and for no other.

The first cost and operating cost of the machine or system must not be greater than any possible saving to be made by its use.

The most important analogy, however, is that from the business or financial point of view. The likeness between scientific management and labor saving machinery in its effect on wages and profits is absolute. Says Mr. Miller:

"When a labor saving machine has been designed for certain work and put in operation in a certain factory, which factory is only one of a number of factories doing similar work, the profits from the use of the machine may be very large because the price obtainable for the work done by it will be based upon the cost of doing the work by the least efficient of the older machines still necessary to be employed on that work in order to supply the demand. But when all the manufacturers have similar machines at work, competition will lower the price to the ordinary return on capital invested in that general line of manufacturing.

"Similarly, those who first successfully install a system of management materially better than that possessed by their competitors, may make higher profits until such efficient systems become the regular thing—and no longer. Those who are among the last to adopt a labor saving machine do not make more than regular profits. They simply are obliged to take the forward step in order to make any profit at all, or to remain in business. It is the same with systems of factory management.

"Workmen who operate new labor saving machines may receive more than the ruling rate of wages, one of the reasons for this being the lowered cost of production and greater relative ability to pay higher rates; but in the end, sooner or later, the law of supply and demand will regulate this as it does all other competing or unmonopolized businesses. When the use of the labor saving machine has become general, an owner of such a machine can no longer continue to pay materially higher wages than other and competing users of similar machines.

"In every way, so far as I can see, the effect upon factory employers of the use of labor saving machines and of labor saving systems of management is exactly the same, and their attitude toward them should be the same."

So we see that a system, wisely planned and carried out, may effect a substantial though temporary increase in the earnings of employer and employee alike, and it should be welcomed by both at its face value. Least of all should the workman in the engineering trades—machinery building and the like—place himself on record against it. His business in life is the building of labor saving devices for others to use; and can he object when an improvement of the same type is introduced into his own field?

SOME DIFFICULTIES OF SCIENTIFIC MANAGEMENT.

We have seen that substantial benefits, even though of a temporary kind, may be expected from the introduction of scientific management. We have found no logical reason for the objection of either employer or employee to a wise use of this new labor saving device. Are there any positive dangers in the idea itself or in the operations of those who are promulgating it? That there are such dangers and errors, is beyond question.

The first error is a purely commercial one, born of the zeal of the organizer. The system is not in itself the end, but only the means to an end. The true object is the simultaneous increase of the profits, wages, and good will for all concerned, but a few organizers have mistaken this goal and have focussed their eyes on their pet system, instead of on the results to be obtained.

The second danger is that of obstructing invention and development along new lines. Two tendencies are constantly opposed to each other in management—the tendency toward new invention and the tendency toward standardization. Each is profitable in its place, but it takes ability and courage to balance the two properly. Consider the conditions. An immense mass of data collected at great cost is at hand. These data relate to the most efficient performance of certain operations which have been standardized for years. A new machine or process is then developed which attacks the problem in an entirely new way and with superior results. It is then difficult for the organizer to see his years of standardizing overthrown without making a struggle to save the system.

The introduction of a new system must not tend to block the development of automatic machinery by the desire to preserve the costly data for older processes. The improvement of mechanisms, after all, should be the larger vision of industrial management. With the increase of skill in our designs, the reign of the automatic machine will become supreme. With the hand-fed machine, the workman is like a slave to a master of steel and iron; but not so with the fully automatic, self-feeding mechanism. More and more will our shops approach the ideal shop of the future where the workman, as master, shall move among his servant machines, adjusting this one, changing the work of that one. In such a shop the system organizer would find his work reduced to the minimum, but progress is in that direction and the system must not stand in the way of ultimate success.

The third possible source of weakness in the work of the systematizer, if he has not a clear conception of the fundamentals of his work, is the misunderstanding of the most important element in his problem—the human element. Some fifteen or twenty years ago, during the height of what might be called the "biological period" of philosophy, an engineer might have been pardoned for believing that man is a machine, subject to invariable action under the laws of cause and effect, but we are now beginning to perceive that the laws governing man's actions are infinitely more complex and far beyond the powers of his own intellect to comprehend in their fullness.

There are two sources of trouble from the human factor. One is misunderstanding on the part of the workman. To overcome this requires first of all that the systematizer shall have firm assurance of the justice of his position; and then he must have tact, determination, and a real liking for the man he deals with. Confidence, willingness and enthusiasm must be built up on the solid foundation of square dealing. The second source of trouble from the human factor is a corollary of the first. The organizer must have the right attitude toward the men under him. The cause of scientific management has suffered much in this matter from some of its chief exponents. Originating as it did in the steel mills, with their vast armies of ignorant and unskilled workmen, it is natural that the system in its origin should have treated these men as so many machines, but even these men are mighty reservoirs of spiritual forces, before which laws of averages and tables of motion study are mere straws in the wind; and when the same attitude is carried into dealings with skilled and intelligent men, the scheme becomes hopelessly unworkable. It would have been better for the cause if some pages of its most authoritative tracts had never been written. There breathes through them, in spite of their protests, the feeling that the mission left to the workman is the mission of a machine—that his effectiveness to himself, his country, and the world, is measured accurately and absolutely, by his output per hour in the factory. Such a view is false. The aim of the existence of the meanest laborer and the greatest captain of industry are alike—growth in individuality, character and social service. Scientific management may and sometimes does include all of these; where it does not, it is doomed to failure and deserves it.

* Abstract of paper read before the American Society of Swedish Engineers, Brooklyn, N. Y., April 20th, 1912, and published in *Machinery*.

The Pressure of a Blow—II*

And the Impact of Projectiles on Armor Plate

By Prof. Bertram Hopkinson, M.A. F.R.S., M.Inst.C.E.

Concluded from Supplement No. 1902 page, 371

If for the bullet of lead previously considered we substitute one of hardened steel which will not flow, the problem of determining the pressure produced by the impact at once becomes much more complicated. In order to reduce it to its simplest terms, and to bring the theory into such a form that it can be tested in the laboratory, we may suppose that instead of the bullet we have a cylindrical steel rod, say ½ inch in diameter by 10 inches long, with flat ends, and that it strikes quite fair against an absolutely unyielding surface. The latter condition could not be fulfilled in practice, because there is no substance more rigid than steel. So far as the effects on the rod are concerned, however, it can be fulfilled by making two rods, moving with equal velocities in opposite directions, collide end on; and this device has been used in the laboratory for imitating the effect of impact against an unyielding surface. We have to consider how long it takes to stop the rod under such conditions. When the end first strikes it is pulled up dead, just as in the case of the lead bullet, only it does not now flow out sideways. The pressure, however, set up at the end of the rod cannot be instantaneously transmitted through it, and consequently the hind parts do not at once feel this pressure, but continue to move on as before. The pressure travels with the velocity of sound, which for steel is about 17,000 feet

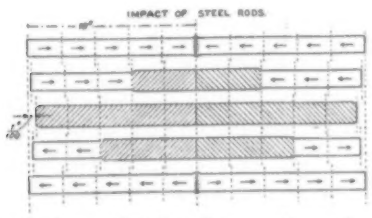


Fig. 2.—Portions of Rod in Compression and at Rest Shaded. Relative Velocity at Impact 34 Feet=400 Inches Per Second. Pressure About 13 Tons Per Square Inch.

per second, and it takes accordingly 1/20,000 part of a second before the pressure has been transmitted throughout the 10 inches length of the rod. The course of the impact is shown in the diagram (Fig. 2). A wave of pressure is imitated at the first contact and travels along the rod. At any instant the part of the rod which has already been traversed by the wave will be at rest and in compression (as indicated on a greatly exaggerated scale by the shortening and thickening on the diagram), while the remainder which has not been reached by the wave, and accordingly as yet knows nothing of the impact, will still be moving forward with the old velocity. Each section continues to move on until the wave reaches it, when it is stopped with a jerk, the sections thus pulling up successively until the whole rod is at rest, which happens when the wave has traveled to the free end. From the momentum of the rod, and the time taken to stop it, the pressure can be calculated by the use of the principles already illustrated. Thus a rod 10 inches long is stopped, as we have seen, in 1/20,000 second, and if it be moving with the moderate velocity of 17 feet per second, the pressure required to pull it up in this time is 13 tons per square inch. This pressure is constant throughout the impact, and it is obvious that here again the intensity of pressure is dependent only upon the velocity and not on the weight of the rod. For if with the same velocity the length is increased, the corresponding increase of momentum to be destroyed is cancelled by the greater time required for the transmission of the pressure wave, and if the area is increased, the total pressure is merely increased in proportion, the pressure per unit area remaining the same. For a hard elastic body the pressure is proportional to the velocity, a principle which is probably generally applicable in the initial stage of all impacts.

At the instant of greatest compression, when the rod is reduced to rest, it is like a compressed spring, and there being no pressure acting at its free end to keep it compressed, it proceeds to expand again. Starting at the free end a wave of expansion travels down the rod, the several portions being successively jerked into motion with approximately the original velocity. The whole process of restoring motion to the rod is completed when this wave reaches the impinging end, when the rod rebounds as a whole with the original velocity. The whole time of contact is then that taken by a wave of sound to travel twice the length of the rod. Here, again, by electrical measurement of the time of contact, it is possible to check the theory. It is found that the actual time is longer than that predicted. This is due to the fact that one cannot in practice make the rods hit absolutely true all over the ends; they strike at one point first, and the metal near that point has to be flattened out before the ends come into contact all over and initiate the simple plane pressure wave of the theory. The complete analysis of the discrepancies between theory and experiment so caused was long a puzzle to physicists interested in these matters. It was finally effected by Mr. J. E. Sears, who determined mathematically the corrections necessary on this account, and submitted his theory to experimental test with entirely satisfactory results.[2]

Another simple instance of the propagation of waves along rods illustrates a point of importance in regard to the general effect of blows. Instead of maintaining the pressure during the whole passage of the wave up and down, as in the end-on impact, a pressure is suddenly applied to one end, maintained for a short time, and then removed. A corresponding pressure wave travels along the rod. Each portion of the rod is only stressed or in motion during the passage of the wave over it, and after the passage of the wave it is left with a certain forward displacement, but without any velocity or stress. Furthermore, the whole momentum of the blow is concentrated in the short length of the rod covered by the wave. On its arrival at the other end the wave is reflected, but the reflected wave is a wave of tension. As it comes back the head of the tension wave is at first wholly or partially neutralized by the tail of the pressure wave, but after a time it clears this, and the rod is then put into tension of amount equal to the original pressure. If there be a crack or weak place in the rod at a sufficient distance from the free end, the pressure wave will pass over it practically unchanged; but on the arrival of the reflected tension wave the rod will part, because the crack cannot sustain the tension, and the forward part will move on, having trapped within it the whole momentum of the blow. The rest of the rod will remain at rest and unrestrained (Fig. 3)

The fact that a blow involving only pressure may, by the effects of wave action and reflection, give rise to tensions equal to or greater than the pressure applied, often produces curious effects. I shall choose by way of illustration some observations which I have been making recently, and which I think are new. A small cylinder of gun-cotton is detonated by means of mercury fulminate. This means that in an excessively short time it is converted into gas at a very high temperature. The time required is probably only 3 or 4 millionths of a second, and is so excessively short that the gas does not during the process expand appreciably into the surrounding atmosphere.

Thus the gas generated, which, when completely expanded, will fill a space several thousand times as great, is for a minute fraction of time confined within the volume of this small fragment of gun-cotton. This confinement implies great pressure, how much is at present a matter of doubt. I understand that Sir Andrew Noble estimates it at 120 tons per square inch. The only thing which restrains the expansion of the gas is the inertia of the surrounding air, and the pressure accordingly drops with very great rapidity. It is probable that the pressure is practically gone after 1/30,000 of a second. The same pressure is, of course, exerted by the gas upon any surface with which the gun-cotton is in contact, and it will be seen that the force so produced has the characteristics of a blow, namely, great intensity and short duration. If such a cylinder of gun-cotton weighing one or two ounces be placed in contact with a mild steel plate, the effect, if the plate be half an inch thick or less, will be simply to punch out a hole of approximately the same diameter as the gun-cotton, just as though it had been struck by a projectile of that diameter. But if the plate be three-quarters of an inch thick, the curious result shown in Fig. 4 is obtained. Instead of a complete hole being made, a depression is formed on the gun-cotton side of the plate, while on the other a scab of metal of corresponding diameter is torn off, and projected away with a velocity sufficient to enable it to penetrate a thick wooden plank, or to kill anyone who stands in its path. The velocity in fact corresponds to a large fraction of the whole momentum of the blow. The scab behaves much in the same way as the piece which we saw would be shot off the end of a rod struck at the other end if the rod were divided or weakened, so as to be unable to sustain the reflected tension wave. The separation of the metal implies, of course, a very large tension, which can only result from some kind of reflection of the original applied pressure, but the high velocity shows that this tension must have been preceded by pressure over the same surface, acting for a time sufficient to give its momentum to the scab.

Wishing to ascertain how and where the separation originates, I caused a two-ounce cylinder of gun-cotton to be detonated in contact with a somewhat thicker plate. In this case no separation of metal was visible; the only apparent effects being a dint on one side and a corresponding bulge on the other. On sawing the plate in half, however, I was gratified to find an internal crack, obviously the beginning of that separation which in the thinner plate was completed (Fig. 5).

The pressure exerted by the gun-cotton in the experiments which I have just described is practically confined to the circular area of contact between it and the metal,

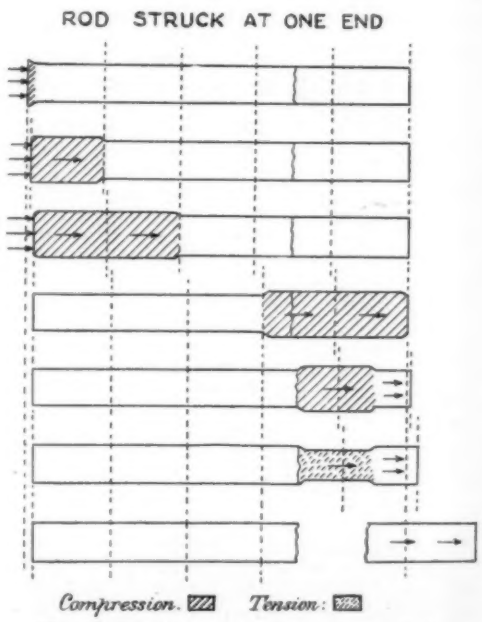


Fig. 3.—Propagation of a Pulse Along a Rod.

as is shown by the accurate agreement of the print on the plate with that circle. The effects of that pressure must, however, be largely conditioned by the fact that the metal upon which it acts is attached to the surrounding portions of the plate, and is held back by them. In order to get an idea of the effect of this factor, I have tried the experiment of removing this outside metal, leaving the steel cylinder opposed to the gun-cotton. If such a short cylinder of steel be placed in contact with a gun-cotton cylinder of equal diameter, the result of detonation was at first sight merely to flatten it out slightly, and to produce a depression on one side with something of a bulge on the other. No external crack was visible. But on sawing the piece in half a remarkable system of cracks was disclosed (Fig. 6); the cracks spread in all directions, as though tension had been acting in every direction; in fact, it appeared as though the steel cylinder had begun to burst. The tension necessary to produce these cracks, which, as you will see, must have radial as well as axial components, must originate in some kind of wave action which follows the blow. The problem is very complicated, and I have not yet succeeded in finding a full explanation of the phenomenon; but there cannot be much doubt that the longtitudinal tensions are due to a wave generally similar to that which we have been discussing in connection with the rod. To account for the radial tensions which the cracks show also to have been present, it is to be observed that the shortening of the cylinder in the direction of its axis, which is the immediate effect of the blow, must be accompanied by a corresponding increase in diameter. This increase takes place very rapidly, and implies that at first the metal is moving out in a radial direction with a high velocity. The stoppage of this radial motion requires radial tension, and probably this is greater at points near the axis for much the same reason that when a stone is dropped into a pond the circular waves which it causes have their greatest amplitude at points near the center of disturbance. In

*Paper read before the Royal Institution of Great Britain.

[2] Camb. Phil. Soc. Trans., vol. xxi., p 49.

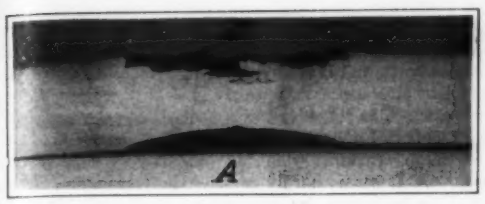


Fig. 4.—Section of Mild Steel Plate, ¾ Inch Thick, After Detonation of Gun-Cotton in Contact with the Side *A*. Scab Torn Off from *B*.

the case of the steel cylinder the radial tension wave travels inward from the surface, and its amplitude increases as it goes in.

I have recently been attempting to measure the duration of the pressures produced by the detonation of gun-cotton. The principle of the method may be made clear from the diagram showing the effect of a blow on one end of a rod (Fig. 3). A wave of compression travels along the rod, the length of the wave corresponding to the time during which the pressure has acted; that is, it is equal to the velocity of sound, multiplied by that time We may assume that the time was 1/20,000 of a second, which would give a wave just 10 inches long. This wave travels to the end of the rod, is there reflected as a wave of tension, and comes back. If the rod be cut across, the surfaces of the junction being accurately faced and in firm contact, the pressure wave will pass the joint without change, but on the arrival of the head of the tension wave at the joint, the parts will separate and the end piece will fly off. If the tail of the pressure wave has then cleared the joint, the separated end-piece will have trapped within it the whole momentum of the blow, and the part left behind will remain at rest and unstrained. In the case supposed things will happen in this way if the end-piece is more than 5 inches long. If it be less than 5 inches long, say 4 inches, there will, on the arrival of the reflected wave at the joint, be still 2 inches of pressure wave in the other part of the rod, and the corresponding quantity of momentum. In this case, therefore, only a portion of the whole momentum is trapped in the piece, the balance being left in the other part of the rod, which moves forward with the corresponding velocity. In order to discover how long the pressure lasts it is only necessary to try a series of experiments with the joint at different distances from the free end. It will be found that if that distance exceeds a certain amount, the rod which was originally struck remains at rest, the whole momentum being transferred to the free end-piece. If the distance be less, only a fraction of the momentum is so transferred, and the balance remains in the struck rod, which accordingly moves forward.

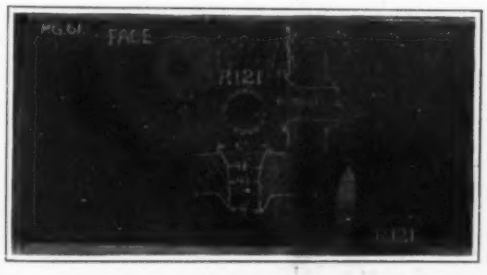


Fig. 8.—The Effect of Firing an Uncapped Shell on a Plate of Mild Steel.

I have applied this method to investigating the curve of pressure developed by the detonation of gun-cotton. I will not weary you with the details, but the results, so far as I have obtained them, are shown in the curve (Fig. 7). This exhibits the pressure produced by the detonation of one ounce of dry gun-cotton on the end of a steel rod, distant three-quarters of an inch from it. With the gun-cotton hard up against the steel the pressures are probably about twice as great, and the curve similar in form.

Time will not permit of my going further into the interesting question, of course a very important one in connection with our subject, of the effect on the character of the fracture produced of very big stresses lasting for a very short time. The fracture of mild steel by gun-cotton shows, however, that one result may be that the property of ductility largely disappears under the action of a sufficiently violent blow. The mild steel, in fact, behaves very much like sealing-wax, or pitch. A stick of sealing-wax may be bent double by the continued action of a small force acting for several days. Yet under the application of a force many times as great, it snaps like a piece of glass.

The pressures produced by the detonation of gun-cotton are of the same order of intensity as those developed in ordinary blows. We saw that in the impact of billiard balls the average pressure over the area of contact may reach a value of 27 tons per square inch, and with steel balls moving at quite small velocities, such as

Fig. 5.—Section of Mild Steel Plate, 1¼ Inch Thick, After Detonation of Gun-Cotton in Contact with the Side *A*. Crack Formed at *a*.

2 or 3 feet per second, it is easy to get pressures of 100 tons per square inch or more. These pressures, however, are very local, the area over which they act being a few hundredths of an inch in diameter only. By means of gun-cotton similar pressures may be applied over any desired area; but the intensity is no greater. About 120 tons per square inch is probably the limit of simple static gaseous pressures produced by known practical explo-

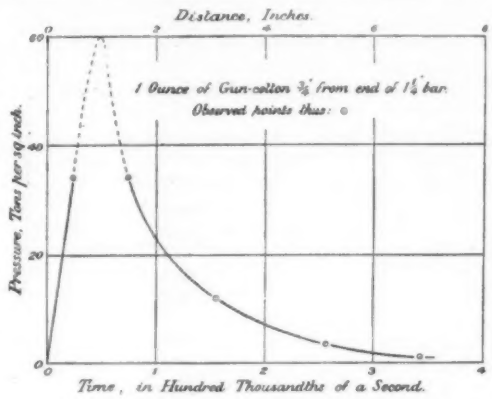
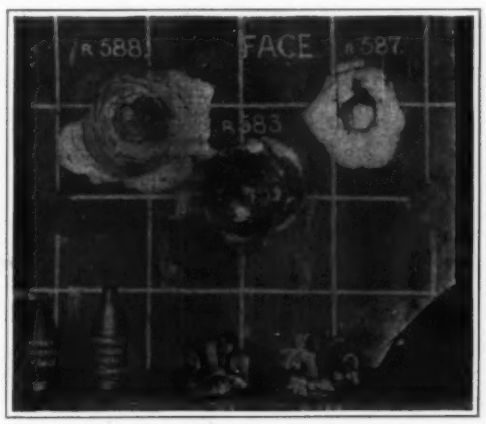

Distance, Inches.
1 Ounce of Gun-cotton ¾ from end of 1¼ bar.
Observed points thus: ○
Pressure, Tons per sq inch.
Time, in Hundredths of a Second.

Fig. 7.—Pressure Produced by Detonation of Gun Cotton.

sives. Probably greater pressures are produced with fulminate, but that cannot be used except on a very small scale. For the production of destructive effects on hard steel greater pressures than this are required, and in order to develop them on any considerable scale we must again have recourse to the dynamic action of collision.

We have already seen that a lead bullet moving at 1,800 feet per second probably generates a pressure of



TEST OF PLATE.

1. Round 583. Hadfield's Cast Steel A.P. Shot (British Standard) Uncapped.

Striking Velocity	Energy—Foot-tons	Factor of Penetration
2010	920	2.33

Round 588. Hadfield's Cast Steel A.P. Shot (British Standard) Uncapped.

Striking Velocity.	Energy—Foot-tons.	Factor of Penetration
1930	840	2.18

Fig. 9.—Trial of "Era" Steel Hard Face Armor Plate 4 x 4 Feet x 4⅛ Inch.

200 tons per square inch or more. We went on to consider the impact of rods of hard metal, and it appeared that two rods of steel colliding end on with a relative velocity of 34 feet per second would develop a pressure of about 13 tons per square inch over the whole section of either. The theory on which that conclusion is based has been subjected to experimental test—indirect, it is true, but sufficiently searching—and is certainly correct for velocities and pressures of that order. According to the theory the pressure is simply proportional to the relative velocity of the two rods, so that if they collided at 2,000 feet per second, that is sixty times as fast, the pressure would be 780 tons per square inch, assuming

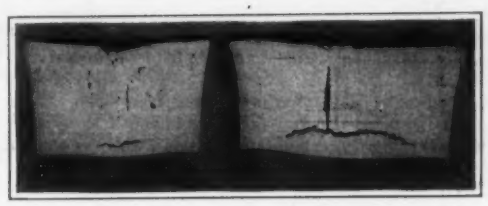


Fig. 6.—Axial Sections of Steel Cylinders, After the Detonation of Gun-Cotton in Contact With One End.

that the theory continues to hold under these very different conditions.

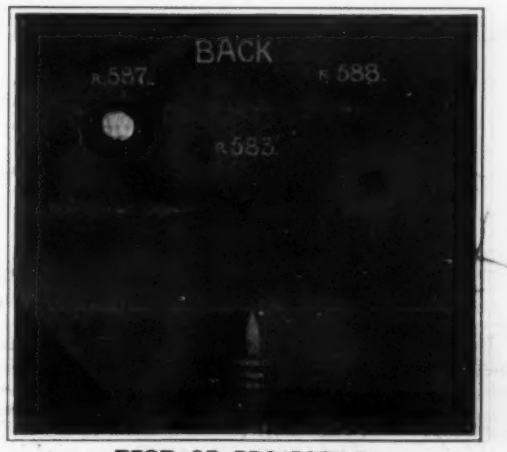
One of the fundamental assumptions on which the theory is based, however, would certainly break down long before such a velocity was reached. That assumption is that the pressure leaves no permanent effect on the material. I do not know what is the strongest steel for this purpose which has been produced, but I think it may safely be asserted that no known substance would stand an end compression, such as results from the blow of the colliding rods, of more than 300 tons per square inch. If it were ductile it would flow so rapidly under this pressure that there would be appreciable deformation even in the very short time during which the pressure lasts If it were very hard it would be instantly shattered. In both cases the circumstances of pressure transmission would be completely altered. It is, however, fairly certain that in neither would the pressure exceed that calculated on the hypothesis of perfect elasticity, and that in both it would be greater than that calculated (as for the lead rifle bullet) on the hypothesis of no elasticity.

I am afraid, therefore, that at present our theories can throw but little light on the interesting question of the pressure developed when a hard steel armor-piercing shell strikes a hard steel plate with a velocity of 2,000 feet per second. But a consideration of the visible effects of such a blow is suggestive in many ways, and by the kindness of Sir R. Hadfield I am able to describe and show some of them here.

The shell of modern armor-piercing shot is made of a special steel of great strength and considerable ductility, and after manufacture the point is hardened by thermal treatment, the base and most of the body of the shell remaining more or less ductile. In recent years it has become the practice to fit a cap of soft steel over the hardened point. I will speak of the functions of this cap later, and for the present we will consider the shell without it.

I first show the effect of firing an uncapped shell at a plate of wrought iron or mild steel (Fig. 8). In this case the metal of the plate is so soft that pressures that are quite without effect on the hardened point of the shell are able to make it flow very rapidly. The shell simply plows its way through, pushing out the wrought iron before it, and emerges quite unscathed. It will be noticed that on the striking side there is a rim or lip of wrought iron which has been squeezed out in a direction opposite to the movement of the shell. A similar lip is formed if a hole is blown in a lead plate by means of a gun-cotton primer, and there seems to be a good deal of analogy between the two cases.

Completely to stop a 14-inch shell would require a thickness of at least 2½ feet of wrought-iron, and almost as great a thickness of mild steel. I believe that some ships twenty-five years ago were fitted with armor of this sort of thickness, but, of course, the weight is almost prohibitive. Modern improvements in armor, whereby the same effective resistance is obtained with less than



TEST OF PROJECTILE.

2. Round 587. Hadfield's "HECLON" Cast Steel A.P. Shell. Capped.

Striking Velocity	Energy Foot-tons	Factor of Penetration
1930	840	2.18

Fig. 10.—Trial of "Heclon" 4⅛ Inch Armor-Piercing Shell of 32¾ Pounds.

half the thickness, are based on the use of special steel having sufficient ductility to enable it to be worked and fixed in place on the ship while possessing greater strength than wrought-iron or ordinary structural steel. Even such a special steel, however, is handicapped as against the shell by the hard point of the latter, which is able to force the softer material aside though itself undamaged. This disability has been overcome by hardening the face of the plate so that the back is tough and ductile, but the face as hard as it is possible to make it. When such a plate is struck by the shell it is a case of Greek meeting Greek, and this is the result (Fig. 9, rounds 583 and 588). Both the shell and the hardened face of the plate are shattered by the pressure, sufficient of which is transmitted through the substance of the plate to crack it right through, though, of course, none of the shell has penetrated it.

It would seem that when it acquired the hard face the armor plate more than over-took the shell in the race. Though the shell might by sheer energy pierce a somewhat thinner plate, I am told that it was apt to be smashed to pieces in the process. The balance has of recent years been more than restored by the addition to the shell of the soft steel cap. I have already shown you the effect of firing an uncapped shell; I will now draw your attention to that of firing the same shell with cap at the same plate (Fig. 10, round 587). The shell goes through minus its cap, but otherwise so completely uninjured, that I am told it might in many cases be used again. It punches a clean hole in the plate. The fate of the cap is interesting. The shell punches a hole in it, as of course it must do before it reaches the plate, and the cap forms a ring, which is held up by the plate and through which the shell passes. The fragments of the cap are found on the front side of the plate, and in some instances they have been collected and put together, forming a ring.

The usual explanation of this remarkable effect of a soft steel cap is that it supports the point of the projectile. As I pointed out in connection with billiard balls, the destructive effect of pressure depends on the difference of pressures in different directions, and not on their absolute amounts, and it is obvious that by the exercise of a sufficient lateral pressure the point might be completely protected. The difficulty is to see how the comparatively weak material of which the cap is made can exert the very large pressures which are necessary for effective support. It seems hardly possible that such pressures could be generated by the mere act of stretching or expanding the cap over the end of the shell. If this be so, the inertia of the metal in the cap must play an important part. At the critical moment when the hard point of the shell meets the plate, there is sudden distortion of the shell and plate near the point of contact. This distortion is the cause of breakage. One can see the mass of mild steel surrounding the point of the shell, and pressed into firm contact with it, might by its inertia oppose a powerful resistance to this sudden change of form, and so support the shell during the minute fraction of time which determines whether it or the plate shall go.

On the Trail of the Subconscious*

The Byways of the Mind

By Prof. Joseph Jastrow

To many "the subconscious" suggests an adventure in darkest psychology. It is a popular notion that we each harbor in the obscure recesses of our minds a sort of understudy, a subconscious personality, an irregular proxy, who occasionally comes forward in startling revelation, and projects the thoughts and behavior of an under-mind—according to others, of a super-mind—into the even tenor of our ways. Some propose to train this mysterious counterpart to act as a useful deputy; they persuade us to believe that if the conscious struggling self will relax and fall back on this deeper, truer, hidden insight, go into a trance or on a vacation, the self will come into its own and find the solution of perplexities knocking at the door of consciousness. The subconscious has been pictured as an elusive, superior wraith and as the most familiar of companions. The truth is that its life is neither so obscurely black nor so transparently white as it has been painted.

So long as we are mentally alive, consciousness is variously busy; but it is not a meddlesome busybody. It goes about its many-sided affairs with a poise and a directness of purpose that is possible only through close organization and long training. It goes where it is wanted and directs only so far and so long as is profitable The mental economy demands a regulated superintendence, but an extremely complex and elastic one; it is ever ready to take charge, ever keeps in touch, even when seemingly off guard. When all runs smoothly, the mechanism is least conspicuous. There may be a fussy or nervous over-superintendence; a simple case thereof is that of a too intent swallowing of a pill, which sticks in the throat because there is more directive effort than such a lowly business warrants; we swallow our food subconsciously, easily and naturally. We walk naturally, not when we think most, but when we think least about it. What bridal couple ever walked to the altar with a natural gait! How difficult to get a natural pose or expression in a photograph, to be "taken" consciously intelligent yet subconsciously unaware. Clearly our habits, disciplined and spontaneous, which form our second nature, are our real understudies; we get a direct glimpse of them when we catch the habits at work under diminished superintendence. For this we must relax toward "absent-mindness." I find that my understudy can wind my watch when I dress for the evening, and make me wonder who did it when I try to wind it again at bedtime; that "he" can direct my steps and take me halfway to the university when my errand is in the opposite direction at the post office; that he can lay aside my eyeglasses and give me quite a chase on the trail of the subconscious to recover them. Yet the subconscious is as much of a fairy as an imp and in reality very little of either, but for commonplace purposes a fairly satisfactory and often unreliable caddy, with a caddylike sporadic psychological attack of stupidity, or inspiration, or good luck.

It is the limits of the subconscious that attract interest. Its commonplace behavior is familiar, but by the same token significant. It seems natural that I should walk subconsciously, far less so that I should talk subconsciously, almost incredible that I should write subconsciously. Such statements require analysis to extract their meaning. I keep on walking while my mind is otherwise engaged so long as the footing is easy, but pick my steps on muddy or slippery ground. I am keenly conscious of every step as I cross a trench on a narrow plank. If, instead of a shallow trench, there were a deep chasm with noisy rapids below, I might decline the venture, though quite convinced that the plank had not shrunk in width or lost in strength. If the gangway is provided with a railing I do not hesitate, and cross without touching it. It is a material railing, but a mental, or, if you like, a moral support. Clearly, walking may be steeped in consciousness; which means that it may be involved in considerations and anxieties. In talking, the trained mechanism is slighter, and considerations make far larger demands. To have it go on with much lowered conscious direction would involve something of a mental lapse. Here we approach the unusual, and presently the abnormal. Some persons frequently, though briefly, talk in their sleep; many sleepers can hear and answer a question without awakening. For various reasons sleep-walking demands a more serious departure from the normal than sleep-talking: Lady Macbeth combines both in her guilty unrest. As to writing, the mechanical part is for fluent writers trained to a lowered direction. It is a common experience to find oneself copying from a page accurately, with thoughts far afield. To compose as well as write in sleep or in a trance would be strange indeed; but why?

That is another story, but one that needs to be told. If you inhale a few whiffs of ether, you become sense-less and thought-less and will-less together; and when you come to, you resume feelings, thoughts and control—at first dazedly, after a while alertly. In waking from sleep you seem to pass from unconsciousness quickly to consciousness. The less traveled trail of the subconscious leads to *partial* resumption. Somnambulism is a partial or irregular resumption of one kind. In a more gradual release from the disabilities of an anesthetic, the mental functions resume irregularly; snatches of expression, violent gestures, passive dreams, imaginative constructions accompany the unfettering of the mind—at times handed over to the memory of the waking consciousness, more often fragmentary or lost. Drug intoxication makes strange invasions into the vagaries of consciousness, calls out visions, releases controls and reserves, brings forward suppressed and unsuspected resources of inner experience. Most enlightening because subject to the play of experiment, is hypnosis, an artificial trancelike state, in which suggestion plays upon the mind's stops. From many sources of evidence we may formulate *what* it is that we resume. First of all, we resume and maintain an alert relation with the world about us; we feel, and see, and hear. Again, we fit feelings and thoughts into a continuous many-stranded coil of inner experience. In resuming we find the mental book-mark and go on to the next page with a fair knowledge of what has gone before to make us what we severally are. Finally, we do not passively resume or receive the returning self, but take the initiative, take the reins in our hands. The same old self goes on in the same old world with the same old tasks, yet ever with a touch of novelty that demands the alert consciousness of a new combination, possibly a strenuous pulling together of ourselves, subjecting its success to a happy support of conscious and subconscious participation.

Partial resumptions are as properly called partial lapses; they are as characteristic in the mental obligations that are met as in those that are ignored. In absent-mindedness, distraction or "wool-gathering" the full waking privileges are slightly in abeyance; in somnambulism and hypnosis they are irregularly resumed, the direction of resumption following the clue of imposed suggestion. The hypnotized subject is for the moment asleep; but my suggestion reaches his altered consciousness so peculiarly that he acts upon it, apparently sees, hears, walks, talks, commands his muscles, his words, and his ideas; yet is unaware of his surroundings, is alienated from his normal self, when awakened knows nothing of the strange antics he has performed while hypnotized; left without suggestion shows no initiative, as to the suggestion he offers little or no resistance. Hypnosis is a selective alteration of consciousness, dissipating its unity, confining the world—like Lady Macbeth's nocturnal penance—to the imposed quest or task.

The hypnotic consciousness, like the more normal subconsciousness, is a detached consciousness, or a state of dissociation. In that state the normal consciousness is not wholly put out of commission, but plays the subordinate part, not unlike the role of the subconscious in the normal state. I tell the hypnotized subject that he cannot write the letter *a* and ask him to copy "*Alabaster from Madagascar.*" He writes "*Albster from Mdgscr,*" but must have seen the *a's* just as clearly to know where to omit them as where to insert them. In order to "cut" an acquaintance, the undesirable citizen must be seen and recognized. Is it all sham, then? By no means—difficult as it is to draw the line between belief and make-belief. If I give my hypnotized subject a paper dagger with instructions to thrust it into the body of the man lying on the bed, he carries through the operation; if I give him a steel dagger and the man is of straw, he also commits murder; but if both dagger and man are genuine, what then? If he balks in the last instance, does it not indicate that some detached phase of the handicapped consciousness recognizes the unreality of weapon or victim, permits the dominant hypnotic consciousness to carry through the project in the first two situations, checks the hand in the last? There is in this altered and imposed relation an "other consciousness" restraint. For the normal status, to a slight extent, some actions will be become detached and be performed subconsciously; in hypnosis some little normality remains and imposes its limitations.

Momentary states of partial resumption of waking privileges seem explicable if they are both brief and light; if long and deep, particularly if recurrent and connected, they extend the conceptions of the mind's waywardness toward the abnormal. I speak of my dream *states*, but not of my dream *self*. Dreams are mere transient interruptions of my waking consciousness, detached, irregular, despite some measure of persistent traits and clear kinship in thought and emotion, in knowledge and desire, with the self I think I know. Somnambulists have been known to somnambulize in serial form, finding in the next seance objects hidden in the previous one, and inaccessible to the waking self. Somnambulists, fearing that they may rise and leave the room, have hidden the key of the door, only to find that the subconsciousness that directed the sleeping enterprise was equal to finding it; but retorted by dropping the key into a basin of cold water, trusting to the shock to arouse the normal consciousness to its responsibilities. Here we have the house of mind divided against itself; it is only when such schemes arise that we learn how far the subconscious can usurp the throne or alternate in rule. The normal issue, despite warring factions, conflicts of impulse and conscience, the snubbed and starved and socially suppressed cravings, hopes, ambitions, the dramatic potential selves that fate compels to live in imagination only—is a unity, an individual, a character; yet in each instance this is an achievement, however common, and seemingly inevitable. We all harbor the possibility of instability, or disruption, as we grow through the psychological ages of man; the storm-and-stress of adolescence makes the issue uncertain, injects the factors of internal dissension, drives from hearth to cloister, from folly to tragedy. Knowing as we do the precarious vicissitudes of personality, what wonder that here and there the fissures dividing the dominance of mood, the direction of conduct in an unstable brain

* Reproduced from *The Independent*.

extend to an involved, persistent or recurrent chasm. Then we have "The Dissociation of a Personality," far more perplexing in the fact as related by Dr. Prince[1] than in the "Jekyll and Hyde" of fiction. To find one systematized consciousness spitefully taking vengeance on its alternate, both housed in the same tenement of clay, seems a preposterous issue. Yet the feminine Hyde would entangle furniture, pictures and her body in endless yards of worsted and wake up her Jekyll counterpart to cut a way out of the maze; the robust Hyde would walk miles out of town and leave the feeble Jekyll stranded without a cent of carfare for the journey home; the crafty Hyde would induce the victimized Jekyll to tear up a ten-dollar bill under the belief that it was a worthless scrap of paper. Extreme, abnormal, is all this assuredly; yet observe that, while the common body that is swathed in yarn, the common legs that carry their owner for miles, the common hand that tears the money, offer no protest until the distracted consciousness is in command, yet the fact that these pranks are no more serious indicate the subconscious concern of the suppressed self; and no less must the subconscious presence of the perpetrator be assumed to assure of the enjoyment of her deviltries. Indeed, we can prove it so; for a neutral ground of concession was arranged, and under persuasion and threat a tribunal of arbitration established, the original personality enthroned, the patient cured.

Standing alone such a case seems chaos itself, the very mockery of psychology. Puzzling as it remains, volcanic in eruption and obliterating its tracks, it is natural withal; science recognizes no freaks. Most of all does its grotesque quality lie in this: that all these things were done, not merely dreamed or desired or concocted, but carried through.

In the suppressed field, where action is only thought and feeling, there may be unrest and dissension; but the normalized will quells the mutiny before it arises. Here lies the trail to the limitation of the subconscious; the reason why hypnosis goes so far and no further, why a trance in which altered personality plays its drama keeps to its stage and does not make a stage of the world. The player and the person are two, yet one. Yet the person loses himself in the part. Confusion is possible; the outer world of fact may seem unreal, because of the intense reality of the world of imagination, which is also the world of desire. Unstable characters express the uncertainty of conflict, the obstacles to achievement, the duplicities, conscious and subconscious. It is affectation when the pose lies near the surface, hysteria in its deeper invasion. And though not a blessed word, hysteria is a most significant one—a great highway narrowing in its remoter issues into a tangled trail. Hysteria when mild is psychological instability; when pronounced it is a veritable jungle of psychological contradictions to be made intelligible in terms of subconscious domination. Cases of conflicting, distressed and handicapped personalities are in large measure hysterical, the symptoms indicative of a marked dissociation. The unity of mind must be gained by reconciling the subconscious invasions with the accredited, naturalized dominion.

The depth of the invasion of the abnormal subconscious is decisive. There is a striking tale of a romantic head clerk of Geneva, Mlle. Smith,[2] who on Sunday evenings held seances to impressed circles, in which as "medium," not as actor, she became the reincarnated Marie Antoinette; or, in another cycle, an Oriental princess involved in tangled intrigue; or yet more amazingly, a Martian soul, revealing through an entranced pencil the scenery, the customs, even the language of the sister planet. It is a remarkable performance for a subconscious disciple, but a disciple of the head clerk of a Geneva shop, nonetheless. The detail is convincing. There is a "control," an imaginary lay figure, that directs the revelations; but he knows his place and does not invade (or rarely) the shop or the home of Mlle. Smith. The subconscious is held at arm's length and does not wreck a work-a-day career, but is content with its Sunday evenings at home. But all through the week, in the detached undercurrents, are incubated and hatched those wonderful creations, imaginative, reasoned, yet ever patterned along the lines of the normal endowment. So similarly, but without so marked detachment, problems are solved in hours of meditative brooding or in half-sleep; visions appear in revery; the subconscious resources, sympathetic to twilight, yield to persuasion when remote to an intent summons. Inspiration acquires a psychological, not a mystic meaning.

The trail that started in the open leads to a thicket, beset with the rich undergrowth of our luxuriant mentality; but it is not a blind lead. The subconscious is for the most part an humble, disciplined collaborator and facilitator, in charge of the mental machinery. Being used to turn on cranks and valves, throw in gears and keep things going, he at times turns them on without orders; or when dazed or befogged takes orders from others than his master, or, breaking through discipline, takes a joy ride on his own account. This is all near enough to the normal to be intelligible. The fundamental reason why there may come to be in unusual cases an abnormal subconscious life, is that in all cases there is necessarily a normal range of subconscious thought and action. It is easy by overlooking the valleys and the lowlands to look upon the hills as mysterious upheavals. All normal uses make possible abnormal abuses. Because it is good for man to use his mind and fear the fearful he is liable to fears that are in vain; because it is his privilege to regulate his life by reasonable beliefs, he is prone to upset his peace of mind by superstitions; because his mental endowment is complex enough to achieve and appreciate the great things of human life, it is open to the hazard of high endeavor. The consistency, the singleness of the normal issue, sets in striking contrast the waywardness of rival personalities. True enlightenment lies along the highways, however alluring the byways of the mind. To maintain the conception of the subconscious on a profitable level, it is important to emphasize its normal kinships as well as its queer relations. Sanity of view, like sanity of life, is ever an achievement, but happily one equally within the compass of the lowly and the great.

[1] Morton Prince: "The Dissociation of a Personality." New York. Pp. 569. See also Joseph Jastrow; "The Subconscious." Boston. Pp. 549.

[2] Flournoy: "From India to the Planet Mars." 1900, pp. 447.

The Gaumont Speaking Kinematograph Films*

The Phonograph Synchronised With Moving Pictures

JOHANNES MÜLLER, one of the greatest physiologists of the last century, when considering the time factor in nervous processes, was so impressed with the inherent difficulties of the question, that he said, "We shall probably never attain the power of measuring the velocity of nervous action, for we have no opportunity of comparing its propagation through immense space as we have in the case of light." As is often the case, when the forecast is darkest light is near. As it has in the case of determining the velocity of a nervous impulse by Helmholtz so it has in the synchronization of the kinematograph and phonograph. The question of synchronization of a camera and a talking machine is a problem that attracted the attention of Edison himself from the time of his invention of the kinetoscope, an instrument, however, in which only one person at a time could see the moving picture.

It is not enough to have a perfect synchronism between the phonograph and the kinematograph—between the talking machine and the camera. The vocal sounds of one or more speakers must be registered at a distance of several yards from the phonograph. To do this without altering the purity and intensity of the sounds emitted is no easy problem.

Obviously the phonograph and kinematograph must be placed in the same electrical circuit. Experience has shown that the phonograph must control the action of both instruments. In July, 1901, the Gaumont Company obtained the first patent for such an arrangement.

The problem is how to obtain *at the same time* records from a kinematograph and from a phonograph, gramophone, or talking machine, and, having obtained these, how can they be reproduced and presented *simultaneously*, the one record to the eye and the other to the ear, so that a large audience—even six thousand in number—shall be able to see and hear that all marches in unison and produces an illusion so complete as almost to represent real life.

In the ordinary speaking and moving pictures which have been presented hitherto, the actor or singer has just to speak or sing into a phonograph placed close to his mouth, whereby a record is obtained. This is reproduced on an appropriate machine, and when he hears the sounds he makes as best he can the appropriate sounds, movements, and gestures while the kinematograph records. There is no question of *simultaneous recording and reproduction* of the double record. Consequently, the result is not satisfactory, By means of the combination of a camera, a talking machine, and a megaphone, the combination being termed by M. Gaumont the chronophone, large scenes as well as the effects of a full chorus are obtained at one and the same operation.

At first sight it might seem as if the problem of producing *simultaneously* combined pictorial and audible records was a comparatively simple one. It is, however, far from being so. We may lay down the following conditions:

(1) Absolute synchronism between the phonograph and the kinematograph both in recording and reproducing the result.

(2) Registration of sound by the phonograph at a sufficient distance at the same time as the registration of the pictures on the moving film, without the phonograph being in the field of the kinematograph.

(3) The amplification of the sound so that a large audience can hear the sound and observe the exact correlation between the movements of the speakers, or actors, or singers, and the audible sounds as regards pitch, loudness, and quality of the vocal or other sounds.

It has been calculated that in a record on an ordinary 12-inch disk of a gramophone the length of its sinusoidal sound line or spiral groove—counting 100 grooves to the inch from the center to the circumference of the disk—is about 240 yards, or 720 feet. If, however, the ripples made by the vibrating stylus as the disk revolves under it at the rate of 32 inches per second be added, it brings up the total length of the sound line—in the reproduction of a sound record lasting from three to four minutes—to, it may be, 500 yards, or 1,500 feet. The disk makes about 76 revolutions per minute, or an average rate of each revolution in 0.8 second.

In order to produce what M. Gaumont has called "filmpariants," or speaking kinematograph films, two motors of identical pattern actuated from the same source, and of approximately the same power, are used for driving the phonograph and the kinematograph. A rheostat introduced into the circuit enables the operator to vary at will the velocity of the motors, even when they are in action.

Experience has shown that the best results are obtained by first setting in action the dynamos and the phonograph. The kinematograph is not engaged until a given moment. This can be arranged by placing a clutch between the kinematograph and its motor. The automatic engagement apparatus is controlled by a lever connected with the armature of an electromagnet, which is actuated at a given moment which corresponds with a definitely determined position of the needle in one of the grooves of the disk of the phonograph, which is of the gramaphone type.

If, however, by any chance there is a discord, however small, even a fraction of a second, between the emission of the sound by the talking machine and the movement of the lips of the speaker, there is a special arrangement, called the "differential," by means of which any want of accord between the phonograph and camera can be immediately rectified. The differential gearing, which is placed on the shaft between the kinematograph and its motor, and is actuated by means of a special small motor, is provided with a reversing commutator which enables the operator to control the speed of the kinematograph, either hastening or slowing its movements. The speed of the phonograph remains constant, so that all correction in speed, in order to synchronize the two machines, is done by accelerating or retarding the speed of projection by means of the kinematograph. By means of the differential any accidental displacement of the phonograph needle during the projection can instantly be rectified.

In order that the operator may be in close proximity to the phonograph, and to enable him to make sure that everything works well and to regulate the apparatus, he has before him a rectangular box called "Chef d'Orchestre," but which is practically a "control board," fitted with a voltmeter which acts as a speed indicator, a frequency meter which gives exactly the angular velocity at each instant of the phonograph, a starting gear with a series of resistances, whereby the phonograph is set in motion, and a two-way commutator in connection with the differential motor.

* Abstract of a discourse delivered at the Royal Institution on Friday, May 10th, by Prof. William Stirling.

Adhesive for Sail Cloth.—Small round holes, of about one-fourth inch diameter, often occur in wagon covers (sail cloth) that require repairing, and the regular patching of them would cost a great deal of time and material. For this purpose, a glue of caoutchouc is best adapted. In making it, 18 parts of finely shredded gutta percha in a mixture of 20 parts sulphide of carbon, 10 parts benzole, and 10 parts oil of turpentine are set to steep in a glass flask or the like. When, after a few days, the solution, possibly with the aid of gentle heating in the water bath, is effected, add, while stirring, 42 parts of finely pulverized Syrian or American asphalt and allow it to stand until the last addition has also dissolved. Another composition, in thin fluid form, is obtained by mixing a solution of 10 parts of raw gutta percha in 50 parts of sulphide of carbon, with a solution of 20 parts of asphalt in 20 parts of benzol. In place of asphalt one can use rosin, which must, however, be dissolved with the aid of heat. The places to be cemented must first be cleansed of grease by means of benzine and roughened with a curry comb, or the like.—*Technische Rundschau.*

A Theory of the Welding of Steel and Its Practical Application

By Max Bermann

Fig. 1.—Weld Made by the "Komm" Method.

WELDING may be defined as the junction of two pieces of the same metal in such a manner that the particles of the surfaces of contact are united by cohesion, not by adhesion.

Metallic contact of the surfaces is therefore essential, as oxide or slag prevents cohesion. More or less pressure is also necessary in order to bring the surfaces into intimate contact, unless these surfaces are liquid, in which case no external force is required.

In welding without liquefaction the parts are first made plastic by heating and are then united either by steady pressure or by blows of a hammer. The temperature is more important than the degree of plasticity. Each sort of iron and steel has its definite welding temperature, which depends upon its percentage of carbon. If even one of the pieces is much hotter or colder than this temperature, welding is difficult or impossible, although both parts are quite plastic.

I. ORDINARY OR SOLID WELDING.

In practice very little regard appears to be paid to the essential requirement of pure metallic contact. On the way to the anvil or steam hammer the cinder crust is removed but the parts to be welded are not put together quickly enough to insure clean metallic contact. In some cases pieces covered with a thick crust are successfully welded. In this case it must be assumed that the oxide is reduced by the action of some ingredient of the steel. Carbon, manganese, silicon and phosphorus are the ingredients to be considered, in steel. Iron contains, in addition, a large proportion of slag which forms a flux with the oxide and makes its reduction superfluous.

The carbon of steel conveys oxygen to the interior of the mass by alternate formation of carbon monoxide and carbon dioxide, but the principal agent in the reduction of the crust of iron oxide is manganese, which forms

Fig. 3.—A Bad Weld Separated by Torsion.

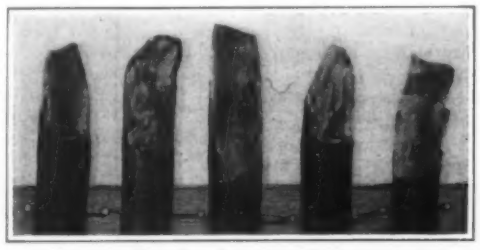


Fig. 4.—Welded Steel Rods Separated by Torsion.

various sorts of steel and to deduce conclusions applicable to practice.

Weldability.—The weldability of a steel depends chiefly on its proportion of carbon, diminishing as this proportion increases and vanishing at a certain limit. Steel which contains a larger percentage of carbon is broken up and consumed when it is hammered at white heat, because the reducing agents are not present in sufficient quantity to effect complete reduction of the oxide.

In many cases very soft steel or malleable iron, which usually is easily welded, behaves in the same manner.

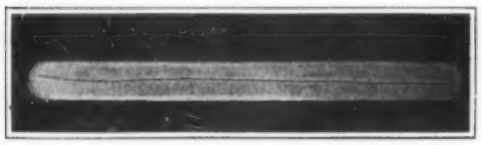


Fig. 5.—Weld Made with Flux at Bright White Heat.

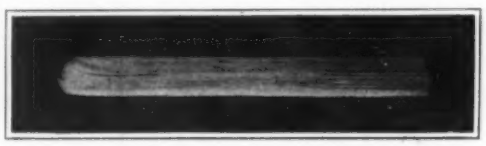


Fig. 6.—Weld Made with Flux at Yellow Heat.

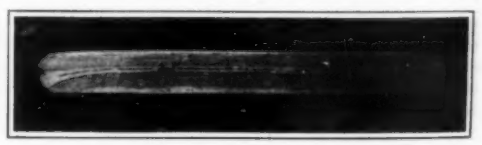


Fig. 7.—Weld Made with Flux at Dull White Heat.

6/10 per cent of the weight of soft steel. This is proved by the fact that the facility of welding increases and decreases with the proportion of manganese. This reducing action takes place when the steel is heated to the welding temperature and is independent of the operation of welding, as the following experiment proves: If a steel rod is drawn from the fire at white heat its temperature suddenly rises, as is shown by a change of color to the bluish-white of the electric arc. The heat which produces this rise of temperature is evidently derived from the rapid combustion of the silicon and phosphorus in the steel, probably by means of oxygen furnished by the manganese dioxide which was formed by the reduction of the superficial crust of iron oxide. Hence it appears that clean metallic contact, the essential condition for a perfect weld, is assured by the reduction of the oxide which covers the welding surfaces. The influence exerted by the temperature upon the success of the operation is due to the dependence of the reaction-velocity upon the temperature. The welding temperature, therefore, is the temperature at which the iron oxide is reduced most rapidly. The observed fact that the facility of welding steel is not appreciably diminished by repeated welding indicates that all of the oxides are reduced in the process of reheating.

The fundamental principle of the theory of welding steel, therefore, is that metallic contact of the minute particles of the welding surfaces is produced, at the welding temperature, by the action of reducing agents contained in the steel. We will now endeavor to explain by this theory the phenomena observed in welding

This phenomenon, hitherto an enigma, is explained by the new theory on the assumption that in these cases the soft steel has taken up carbon from the fuel, as in the cementation process, and has thus been converted into hard, unweldable steel. The same steel may be welded perfectly if it is heated in a furnace in which this transformation does not occur.

The weldability of steel increases with the percentage of manganese present in the metallic form or as carbide, but manganese oxide hinders welding. Silicon promotes welding by reducing the manganese oxide, thereby raising the temperature and preventing rapid cooling.

Fig. 8.—Welds of Martin Steel with Tool Steel, Made with a Flux Containing Coarse Iron Filings.

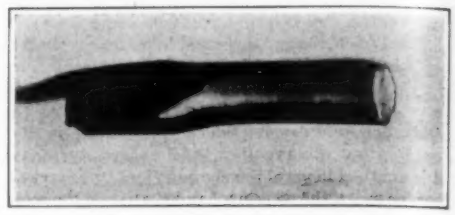


Fig. 2.—A Good Weld, Broken by Torsion.

Silicon oxide, or silica, on the contrary, is unfavorable to welding. Phosphorous in small quantity acts favorably by maintaining the welding temperature, as silicon does.

Perfect Welding.—The success of the welding operation depends upon the thickness of the crust of oxide which covers the welding surfaces. The thinner the crust the simpler is its chemical composition and the more rapidly can it be deoxidized. Small pieces of steel cool before the crust can be reduced and the weld is a failure. A perfect weld can be obtained only when the surfaces have not been oxidized at all or when, after the removal of the crust, they are immediately covered and thus protected from renewed oxidation. These conditions are satisfied in the "Komm" (i. e. "come" or "advance") method of welding rods, in which the crust is removed in the fire, immediately before the surfaces are brought together. The end of each rod is tapered to a point and the rods are placed in the fire with their points nearly in contact and their axes in the same straight line. When the points have attained the welding temperature, these points are freed from oxide and immediately driven into each other by striking the end of the front rod with a light hammer. As the larger parts of the tapering ends successively attain the welding temperature they are freed from oxide and the rods are driven more deeply into each other by repeating the blows. This process produces a weld thicker than the rod.

Fig. 1 shows a micro-photograph of a longitudinal section of such a weld, after polishing and slight etching with weak nitric acid and hydrochloric acids. The absence of lines of demarkation between the two rods shows that the weld is perfect. The completeness of the union can be shown, also, by subjecting the weld to torsion on a lathe or special testing machine. About fifty torsions of 180 degrees, to right and left alternately, are required to break the welded rod, and the surface of fracture is perpendicular to the axis (Fig. 2). Poorly welded rods split longitudinally under this test (Fig. 3) and even rods that have apparently been solidly welded along level surfaces by the usual method separate along the same surfaces after 1 to 15 torsions (Fig. 4). In this case the fracture shows evidence of true cohesion only at the edge, the rest of the surfaces having been joined merely by adhesion.

This result seems to contradict our theory, for if the oxide is converted into pure metal in the fire by reducing agents the weld should be as perfect as in the "Komm" process. The explanation is that sufficient time for the complete reduction of the oxide is available only when the welded pieces are large, unless the reducing substances are unusually active or abundant. As the proportion borne by the reducing agents to the thickness of the oxide crust and the size of the welded pieces is uncertain, the complete reduction of the oxide and the success of the welding operation are largely matters of chance.

The remarkable facility with which malleable cast iron can be welded furnishes another confirmation of the theory. Malleable cast iron is cast iron from which most of the carbon has been removed by heating in presence of oxidizing agents. The superficial layer of such iron usually contains less than 1/20 per cent of carbon and is really a mild steel. The proportion of carbon steadily increases toward the interior, as the surface layer is steel poor in carbon and rich in manganese it furnishes every requirement of weldability.

Another apparent contradiction is found in the good weldability of the so-called welding iron which contains considerable slag. This slag is easily fusible and it must

*Condensed from *Die Zeitschrift des Vereines deutscher Ingenieure*, March 30th, 1912.

be completely expelled from the weld, which would be defective if any slag remained between the surfaces. The desired result is attained by first joining the centers of the surfaces and then squeezing out the slag and extending the area of union, by hammering.

Welding agents.—Hard steel is welded with the aid of fluxes which dissolve the iron oxide, mixed with iron filings which bind the welding surfaces together. The flux or slag must be squeezed out by keeping the weld open until the operation is completed.

Figs. 5 to 9 show sections, polished and etched with acid, of welds made in this way. Figs. 5, 6 and 7 show the results obtained at various temperatures by bending a flat strip of Martin steel on itself and welding the parts together by hammering, with the aid of a pulverized flux strewn between the surfaces. It is evident from the photographs that the welds are not perfect.

Figs. 8 and 9 show welds of Martin steel with very hard crucible steel and with spring steel, made with fluxes containing coarse iron filings. The welds appeared perfect after etching but repeated bending, in the cold, separated the welded surfaces which then showed patches of slag and (in Fig. 8) the separate and very coarse iron filings.

These tests prove that a perfect weld cannot be obtained by means of a flux, unless the iron filings are fused in the operation. The solid filings impede the expulsion of the slag and merely bind the surfaces together by adhesion. It is conceivable that the filings may fuse at the critical temperature in favoring circumstances.

Welding pressure.—A certain amount of external force is required to effect the union of the pure iron parts by cohesion. The magnitude of this force depends upon the dimensions of the objects and their plasticity at the welding temperature. In the liquid state no external pressure is needed, while in the perfectly solid state, at atmospheric temperature, an infinitely great force is required. At the welding temperature easily weldable steel is in a soft and plastic condition, in which very little pressure suffices to unite the particles of pure metal. The welding surfaces, cleaned of their crust of oxide, are driven together by very light blows until they cohere and the parts are then worked into the desired form by heavier blows of the hand hammer, or by means of a steam hammer or press. Heavy blows impressed on the soft steel at the welding temperature would disturb the coarsely crystalline structure which the steel then possesses, and would thus prevent good welding, but light blows bring the individual crystals into intimate contact, thus favoring the reduction of the oxide and the formation of a perfect weld. As the reduction of the oxide, however, is often incomplete, heavier blows or pressures, applied after the surfaces have united, have the effect of breaking up the large crystals and increasing the adhesion, thus producing a practically satisfactory, if not a theoretically perfect weld.

Fig. 9.—Welds of Martin Steel with Spring Steel. Made with a Flux Containing Coarse Iron Filings.

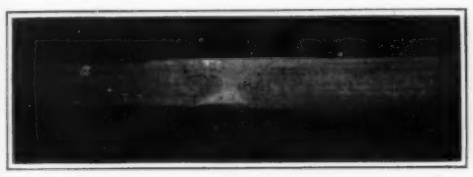


Fig. 10.—Autogenous Weld, Made by Skilled Workman.

Fig. 11.—Autogenous Weld, Made by Apprentice.

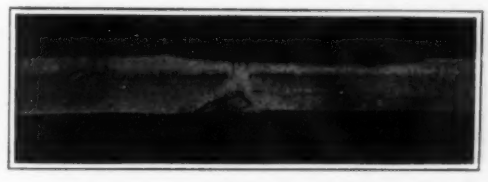


Fig. 12.—Autogenous Weld, Made by Foreman Out of Practice.

Fig. 13.—Spark of Soft Steel Boiler Plates.

The success of the operation depends very largely on the skill and judgment of the smith, especially in welding hard tool steel with soft steel. The hard steel becomes fragile and unmanageable at the white heat proper for the soft steel and its temperature must be kept down to a point at which it remains workable.

After the pieces have been formed they are put together and united by light blows. In this operation the hard steel is also raised to white heat by the rapid reduction of the oxide crust by the agency of the manganese and silicon in the steel, but this does not have the injurious effect of heating to whiteness by the direct action of the fire, because the steel is protected from oxidation and structural disturbances.

Summary.—(a) A perfect weld between pieces of steel of the same kind, or of different kinds, is possible but seldom attainable. It can be assured only by the "Komm" method of welding.

(b) The crust of oxide, which prevents the perfect union of the minute particles of the welding surfaces, is converted into pure metal by reducing agents contained in the steel, and cohesion is thus increased.

(c) The reduction of the oxide is accelerated by elevation of temperature and by increase of the proportion of reducing agents, chiefly manganese, silicon and phosphorus.

(d) The welding temperature is the highest temperature at which the silicon can be forged.

(e) Little force is required to produce cohesion at the welding temperature. After the surfaces have become attached heavier blows or greater pressure should be applied.

(f) A weld is perfect if it breaks transversely, without separating into its original parts, when subjected to repeated flexure or torsion, applied alternately in opposite directions. If, however, the separated surfaces show no trace of oxide or slag the weld is practically satisfactory.

The following suggestions are of practical value:

(1) If a specimen of Martin steel can be forged by hammering at white heat it can be welded without the aid of a flux but if it can be forged only at red heat a flux is required for welding.

(2) Steel should be heated, for welding, in an oxidizing flame; otherwise it may absorb sufficient carbon to make welding impossible.

(3) The welding surfaces should be as large as possible; hence it is advisable to give one piece the form of a wedge, fitting a notch in the other piece.

(4) If the two pieces are carefully fitted to each other before heating a thin crust of oxide will not prevent welding.

(5) Little pressure is required for starting the weld at white heat. This pressure should be applied first to the middle of the surfaces and then quickly extended to the outer parts. After the surfaces have become attached the pressure should be increased.

(6) A weld may be regarded as practically satisfactory if the joint is invisible and is not opened by bending to and fro.

(7) Welding agents are composed chiefly of slag-forming fluxes containing iron filings or fine wires. Unless the iron is so finely divided that it melts at the welding temperature, it rather hinders than promotes welding.

II. AUTOGENOUS WELDING.

The essence of autogenous welding is the intimate union of two surfaces of steel in the liquid state by the interposition of liquid steel of the same composition. The surfaces and the interposed steel are fused by means of a very hot flame, produced by the combustion of hydrogen, acetylene or illuminating gas, mixed with oxygen at high pressure. In these conditions no external force is required to unite the parts by true cohesion. For this reason autogenous welding appears to be far superior to the usual method. Its result might be regarded as perfect, if it were possible to exclude entirely certain unfavorable influences which will now be mentioned.

A perfect weld is characterized not only by cohesive union of the parts but by a uniformity of structure which renders the weld as strong as any other part of the pieces welded together.

In order to obtain cohesive union the welding surfaces and the interposed metal must all be in the liquid state when they are brought together. If the surfaces become solid before the union is effected they are attached only by adhesion and the weld is imperfect. Futhermore, the interposed liquid metal must be free from oxide which, like any other foreign substance, would prevent intimate union of the parts and injuriously affect the uniformity and strength of the weld. Hence it is absolutely necessary that the gas flame shall exert no oxidizing action, but this condition alone does not insure success, for the surface of the fused metal may be oxidized by the air when it is left uncovered by the flame.

Again, when an acetylene flame is used, there is danger of converting the soft steel into hard, high-carbon steel, or even into cast-iron, by a sort of cementation. This transformation may extend beyond the weld itself as is illustrated in Fig. 10, where the dark ring marked *a* has been "cemented" by the flame so that it contains 1.5 per cent of carbon, instead of the 0.07 per cent contained in the other parts of the bar. This result indicates that the cementation is produced, not by the bright white center of the flame, but by the yellow outer zone which strikes the parts adjacent to the weld. In certain conditions acetylene separates into a lower hydrocarbon and free carbon, which combines with the steel and destroys its uniformity of chemical composition.

The uniformity of structure is also affected by autogenous welding which leaves the weld in the coarsely crystalline condition of cast steel. In this state steel is brittle and much weaker than rolled steel. After autogenous welding, therefore, the structure of the weld must be made identical with that of the other parts by forging at the proper forging temperature.

The principal conditions for obtaining a perfect autogenous weld, therefore, are the following:

(1) The supply of heat must be sufficient to melt the welding surfaces and the interposed metal and to keep them in the liquid state until they have completely united.

(2) Oxidation of the fused metal must be prevented or the oxide must be reduced as quickly as it is formed.

(3) The chemical composition of the interposed metal must be identical with that of the pieces to be welded.

(4) The chemical and physical properties of the weld must not be altered by the welding operation.

(5) The weld must be free from voids and air bubbles.

We will now endeavor to learn how these conditions can be satisfied in practice.

The source of heat.—The heat required for melting the steel must be concentrated in one point in order to minimize loss by conduction. It is generated by the combustion of gas of high fuel in pure oxygen under great pressure and is directed upon the welding point in the form of a pointed flame of very high temperature, produced by a jet of appropriate construction. The points to be joined must be fused and united very rapidly, as otherwise so much heat is lost by radiation and by conduction through the adjacent parts and the jet that the welding operation becomes tedious or even impossible. The supply of heat, furthermore, must be so proportioned to the dimensions of the pieces to be welded that the surfaces and the interposed metal can be kept liquid until they have united, despite the unavoidable loss of heat. The heat is regulated by varying the pressure of the fuel gas, the oxygen, or both, and the diameter of the orifice of the jet.

Fig. 14.—Spark of Soft Steel Plate Hardened by Cementation at *a*. (Fig. 10).

The gas may be hydrogen, acetylene compressed in cylinders or evolved directly from carbide in a generator, illuminating gas or, in some cases, benzine gas. Acetylene is recommended by both technical and economical considerations. It is superior to hydrogen for the following reasons: At a high temperature acetylene decomposes and sets free carbon which instantly combines with the steel, increasing its carbon content and elevating its melting point. Hence the liquefied steel is superheated and remains longer in the liquid state. The total quantity of heat required for welding, and the quantity of gas consumed, are consequently diminished.

This conclusion flows from the following experiments. The tires of railway car wheels often show, on their surfaces, very hard grains which break or turn the edge of the hardest and toughest machine tools, and which are usually crushed by hammering or picked out with chisels.

I endeavored to melt or soften these grains with an oxyhydrogen flame but after cooling the grains were as hard as before. When the experiment was repeated with an acetylene flame the familiar moving globules soon appeared and the hard surface was softened in 5 to 10 minutes. The spark test showed that the globules consisted of cast-iron. They had therefore taken up much carbon which must have been obtained from the acetylene. The globules formed in the autogenous welding of soft steel containing 0.07 per cent of carbon were also examined, and were found to contain 0.8 to 1.5 per cent of carbon.

Acetylene would be unsuitable for autogenous welding if this increase in carbon extended throughout the welded mass, but spark tests of the surface and interior of autogenous welds indicate that the cementing action is confined to the stages of red heat and yellow heat and that the carbon set free in later stages is immediately consumed by the oxygen of the flame. Illuminating gas, which is now generally employed in the cementation of steel, probably acts like acetylene in autogenous welding, but experimental proof of this is lacking.

The gas used should be as free as possible from impurities which could injure the quality of the steel. The sulphur and phosphorus of illuminating gas make it unsuitable for autogenous welding, and unpurified acetylene should not be used for very important work. The so-called dissolved acetylene which is purified, absorbed by suitable media and compressed in steel cylinders, best satisfies the requirements if, as is claimed, only pure gas is absorbed by the medium. Hydrogen is suitable only for welding pieces less than ½ inch thick. The heat of combustion of hydrogen is great in proportion to mass but small in proportion to volume. Hence a very large jet and an impracticably rapid outflow of gas would be required for the welding of thick pieces.

Oxidation and reduction of the welding surfaces.—In order to prevent oxidation neither the fuel gas nor the oxygen should be in excess, but this condition cannot be completely realized. With acetylene a slight excess of oxygen is desirable in order to prevent any possible excess of acetylene. The proportion between the two gases should remain constant. The welding surfaces are fused by successive patches, each small enough to be instantly covered by the fused connecting metal, in order to assure intimate union with the latter and to prevent oxidation. The connecting metal is employed in the form of a rod, the end of which is exposed to the flame as near the welding surfaces as possible. As the fused metal drops from the rod it is rubbed against the fused welding surfaces by means of the rod. The various oxides which form in the liquid mixture rise to the surface as a slag, most of which is blown away by the blast or gas. The iron oxide formed on the surface after solidification is reduced by the dioxidizing constituents of the steel. If the steel is very susceptible to oxidation and poor in reducing ingredients, it is necessary to employ welding fluxes which form a slag with the oxide and protect the fused steel from further oxidation.

Choice of the connecting metal.—For welding two pieces of identical composition the connecting metal should have the same composition. This condition is easily satisfied by selecting the rod of connecting metal by the spark test, for specimens of steel that give the same spark pattern have the same composition. The same should be employed in selecting cast-iron rods for use in welding cast-iron objects. The connecting metal should contain sufficient manganese and silicon to insure clean metallic contact and the thickness of the rod should be so proportioned to the dimensions of the weld that the fused surfaces can be evidently and completely covered with liquid connecting metal.

Preparation of pieces for welding.—In order to produce a compact weld free from voids, bubbles and foreign bodies the pieces must be so shaped and placed as to afford the necessary space for the connecting metal and to avoid blocking access of this metal and the flame to the parts yet to be welded by the parts already solidified. Hence the edges or ends to be joined should be oblique and inclined to each other in the form of a wedge, or a double wedge in the case of thick plates which can be welded from both sides. The welding is commenced at the middle of the wedge and gradually extended to the base and toward the ends.

The success of autogenous welding depends entirely on the skill of the operator, which shows itself in the preparation of the surfaces, the selection of a rod of connecting metal of proper size and composition, the estimation of the area to be fused in each partial operation, the choice of a gas jet, the determination and maintenance of the right proportions of acetylene and oxygen and, finally, in the control and application of the flame. The influence of skill in workmanship is illustrated by Figs. 10 to 12, which represent sections of boiler plates about ⅓ inch thick, joined by their edges. All of the plates were of the same material, containing 0.07 to 0.08 per cent of carbon. Each pair of plates was laid on a cast-iron base, with the edges to be joined about ¼ inch apart. This interval was filled by the connecting metal, a soft steel wire containing 0.06 per cent carbon, 0.65 per cent manganese, 0.30 per cent silicon and 0.08 per cent phosphorous. The first pair (Fig. 10) was welded by a skilled and experienced workman, the second (Fig. 11) by an apprentice, the third (Fig. 12) by the foreman and overseer, whose hand had, through disuse, lost so much of its skill that his work (Fig. 12) was a complete failure, and very much inferior to that of the apprentice (Fig. 11). The weld made by the skilled workman (Fig. 10) may be regarded as successful, although the surface of one plate is greatly altered by cementation at *a*. The danger of producing such cementation prohibits autogenous welding of boiler plates and parts of machines subjected to great stresses until it shall be found possible to prevent cementation and to obtain trustworthy proof of the goodness of welds. The question how far this is now possible is discussed below.

The compactness of the weld is injured not only by voids and foreign bodies but also by cracks caused by irregular contraction in cooling. This evil can be prevented by suitable preliminary heating of the pieces to be welded and by guarding against rapid and irregular cooling.

The goodness of autogenous welds.—Autogenous welding is superior to the common method if all of the above-mentioned conditions are satisfied. To test the goodness of the weld three sections must be made along and across the seam. Micro-photographs of the polished and etched sections should show no sharp lines between the welded surfaces and no voids, indicated by dark spots. These tests, of course, are applied only to the practice work of beginners. In other cases the weld is assumed to be good if the metal has not been altered by the operation. The spark test, which reveals very slight changes in composition, is the only satisfactory means by which this fact can be proved. Fig. 13 shows the spark of the steel plate of Fig. 10, before welding, while Fig. 14 shows the spark of the part altered by cementation at *a* (Fig. 10). Spark patterns like Fig. 14 are characteristic of cementation.

This application of the spark test presents no difficulty in practice and the strength of the weld is not injured by the slight polishing required for the formation of a few sparks.

Summary.—(1) Autogenous welding, if perfectly performed, is superior to ordinary solid welding, especially for joining pieces of the same steel, because the fusion of the surfaces facilitates that clean metallic contact between their particles which is the chief condition of success in welding.

(2) Oxides and foreign bodies are effectively removed by slag-forming substances contained in the steel, or added as welding fluxes, if the parts are kept fused long enough. Any iron oxide which is not thus removed is reduced by the deoxidizing constitutents of the steel as in ordinary welding.

(3) A suitable connecting metal can be selected by the spark test.

(4) Alteration of the composition of the steel is prevented by regulating the proportion of oxygen to combustible gas, by adjusting the orifice of the jet or the pressure of the oxygen.

(5) The most suitable gas is purified acetylene.

(6) A compact and homogeneous weld is assured by properly shaping and arranging the welding surfaces.

(7) The crystalline structure of the weld, in important machine parts, must be destroyed by forging.

The Brussels meeting (1906) of the International League for Testing Materials adopted a resolution calling for a scientific study of the problem of welding, to be reported on at the Copenhagen meeting in 1909. This was undertaken by the writer who was still studying the spark test when the Copenhagen congress met.

Modern Mathematical Research*

Increasing Development Exposes New Frontier Regions

By Prof. G. A. Miller

MATHEMATICS has a large household and there are always rumors of prospective additions despite her age and her supposed austerity. Without aiming to give a complete list of the names of the members of this household we may recall here a few of the most prominent ones. Among those which antedate the beginning of the Christian era are surveying, spherical astronomy, general mechanics and mathematical optics. Among the most thriving younger members are celestial mechanics, thermodynamics, mathematical electricity and molecular physics.

Usually a large household serves as one of the strongest incentives to activity, and mathematics has always responded heartily to this incentive. As the most efficient continued service calls for unusual force and ingenuity, mathematics has had to provide for her own development and proper nourishment in addition to providing as liberally as possible for her household. This double object must be kept prominently before our eyes if we would comprehend the present mathematical activities and tendencies.

There is another important incentive to mathematical activity which should be mentioned in this connection. Mathematics has been very hospitable to a large number of other sciences and as a consequence some of these sciences have become such frequent visitors that it is often difficult to distinguish them from the regular members of the household. Among these visitors are economics, dynamical geology, dynamical meteorology and the statistical parts of various biological sciences. Visitors usually expect the best that can be provided for them, and the efforts to please them frequently lead to a more careful study of available resources than those which are put forth in providing for the regular household.

We have thus far spoken only of what might be called the materialistic incentives for mathematical development. While these have always been very significant, it is doubtful whether they have been the most powerful. Symmetry, harmony and elegance of form have always appealed powerfully to dame mathematics; and a keen curiosity, fanned into an intense flame by little bits of apparently incoherent information, has inspired some of the most arduous and prolonged researches. Incentives of this kind have led to the *mathematics of the invisible*, relating to refinements which are essentially foreign to counting and measuring. The first important refinement of this type relates to the concept of the irrational, introduced by the ancient Greeks. As an instance of a comparatively recent development along this line we may mention the work based upon Dedekind's definition of an infinite aggregate as one in which a part is similar or equivalent to the whole.[1]

Mathematics is commonly divided into two parts called pure and applied, respectively. It should be observed that there are various degrees of purity and it is very difficult to say where mathematics becomes sufficiently impure to be called applied. The engineer or the physicist may reduce his problem to a differential equation, the student of differential equations may reduce his troubles to a question of function theory or geometry, and the workers in the latter fields find that many of their difficulties reduce themselves to questions in number theory[2] or in higher algebra. Just as the student of applied mathematics can not have too thorough a training in the pure mathematics upon which the applications are based so the student of some parts of the so-called pure mathematics can not get too thorough a training in the basic subjects of this field.

As mathematics is such an old science and as there is such a close relation between various fields, it might be supposed that fields of research would lie in remote and almost inaccessible parts of this subject. It must be confessed that this view is not without some foundation, but these are days of rapid transportation and the student starts early on his mathematical journey. The question as regards the extent of explored country which should be studied before entering unexplored regions is a very perplexing one. A lifetime would not suffice to become acquainted with all the known fields, and there are those who are so much attracted by the explored regions that they do not find time or courage to enter into the unknown.

In 1840 C. G. J. Jacobi used an illustration, in a letter[3] to his brother, which may serve to emphasize an important point. He states that at various times he had tried to persuade a young man to begin research in mathema-

* Read before the Illinois Chapter of the Society of the Sigma Xi, April, 1912, and republished here in abridged form from *Science*.

[1] "Encyclopédie des sciences mathématiques," vol. I., part 1, 1904, p. 2.

[2] "Der Urquell aller Mathematik sind die ganzen Zahlen, Minkowski, Diophantische Approximation," 1907, preface.

[3] "Briefwechsel zwischen C. G. J. Jacobi und M. H. Jacobi," 1907, p. 64.

tics, but this young man always excused himself on the ground that he did not yet know enough. In answer to this statement Jacobi asked this man the following question: "Suppose your family would wish you to marry would you then also reply that you did not see how you could marry now, as you had not yet become acquainted with *all* the young ladies?"

In connection with this remark by Jacobi we may recall a remark by another prominent German mathematician who also compared the choice of a subject of research with marriage. In the "Festschrift zur Feier des 100 Geburstages Eduard Kummer," 1910, page 17, Prof. Hensel states that Kummer declined, as a matter of principle, to assign to students a subject for a doctor's thesis, saying that this would seem to him as if a young man would ask him to recommend to him a pretty young lady whom he should marry.

While it may not be profitable to follow these analogies into details, it should be stated that the extent to which a subject has been developed does not necessarily affect adversely its desirability as a field of research. The greater the extent of the development the more frontier regions will become exposed. The main question is whether the new regions which lie just beyond the frontier are fertile or barren. This question is much more important than the one which relates to the distance that must be traveled to reach these new fields. Moreover, it should be remembered that mathematics is n-dimensional, n being an arbitrary positive integer, and hence she is not limited, in her progress, to the directions suggested by our experiences.

If we agree with Minkowski that the integers are the source of all mathematics[4] we should remember that the numbers which have gained a place among the integers of the mathematician have increased wonderfully during recent times. According to the views of the people who preceded Gauss, and according to the elementary mathematics of the present day, the integers may be represented by points situated on a straight line and separated by definite fixed distance. On the other hand, the modern mathematician does not only fill up the straight line with algebraic integers, placing them so closely together that between any two of them there is another, but he fills up the whole plane equally closely with these integers. If our knowledge of mathematics had increased during the last two centuries as greatly as the number of integers of the mathematician we should be much beyond our present stage. The astronomers may be led to the conclusion that the universe is probably finite from the study of the number of stars revealed by telescopes of various powers, but the mathematician finds nothing which seems to contradict the view that his sphere of action is infinite.

From what precedes one would expect that the number of fields of mathematical research appears unlimited and this may serve to furnish a partial explanation of the fact that it seems impossible to give a complete definition of the term mathematics. If the above view is correct we have no reason to expect that a complete definition of this term will ever be possible, although it seems possible that a satisfactory definition of the developed parts may be forthcoming.[5]

Among the various fields of research those which surround a standing problem are perhaps most suitable for a popular exposition, but it should not be inferred that these are necessarily the most important points of attack for the young investigator. On the contrary, one of the chief differences between the great mathematician and the poor one is that the former can direct his students into fields which are likely to become well known in the near future, while the latter can only direct them to the well-known standing problems of the past, whose approaches have been tramped down solid by the feet of the mediocre, who are often even too stupid to realize their limitations. The best students can work their way through this hard crust, but the paddle of the weaker ones will only serve to increase its thickness if it happens to make any impression whatever.

It would not be difficult to furnish a long list of standing mathematical problems of more or less historic interest. Probably all would agree that the most popular one at the present time is Fermat's greater theorem. In fact, this theorem has become so popular that it takes courage to mention it before a strictly mathematical audience, but it does not appear to be out of place before a more general audience like this.

The ancient Egyptians knew that $3^2+4^2=5^2$ and the Hindus knew several other such triplets of integers at least as early as the fourth century before the Christian era.[6] These triplets constitute positive integral solutions of the equation

$$x^2+y^2=z^2.$$

Pythagoras gave a general rule by means of which one can find any desired number of such solutions, and hence these triplets are often called Pythagorean numbers. Another such rule was given by Plato, while Euclid and Diophantus generalized and extended these rules.

Fermat, a noted French mathematician of the seventeenth century, wrote on the margin of a page of his copy of Diophantus the theorem that it is impossible to find any positive integral solution of the equation

$$x^n+y^n=z^n \qquad (n>2).$$

He added that he had discovered a wonderful proof of this theorem, but that the margin of the page did not afford enough room to add it.[7] This theorem has since become known as Fermat's greater theorem and has a most interesting and important history, which we proceed to sketch.

About a century after Fermat had noted this theorem Euler (1707-1783) proved it for all the cases when n is a multiple of either 3 or 4, and, during the following century, Dirichlet (1805-1859) and Legendre (1752-1833) proved it for all the cases when n is a multiple of 5. The most important step toward a general proof was taken by Kummer (1810-1893), who applied to this problem the modern theory of algebraic numbers and was thus able to prove its truth for all multiples of primes which do not exceed 100 and also for all the multiples of many larger primes.

The fact that such eminent mathematicians as Fermat, Euler, Dirichlet, Legendre and Kummer were greatly interested in this problem was sufficient to secure for it considerable prominence in mathematical literature, and several mathematicians, including Dickson, of Chicago, succeeded in extending materially some of the results indicated above. The circle of those taking an active interest in the problem was suddenly greatly enlarged, a few years ago, when it become known that a prize of 100,000 marks (about $25,000) was awaiting the one who could present the first complete solution. This amount was put in trust of the Göttingen Gesellschaft der Wissenschaften by the will of a deceased German mathematician named Wolfskehl, and it is to remain open for about a century, until 2007, unless some one should successfully solve the problem at an earlier date.

It is too early to determine whether the balance of the effects of this prize will tend toward real progress. One desirable feature is the fact that the interest on the money is being used from year to year to further important mathematical enterprises. A certain amount of this has already been given to A. Wieferich for results of importance toward the solution of Fermat's problem, and other amounts were employed to secure at Göttingen courses of lectures by Poincaré and Lorentz.

What appears as a bad effect of this offered prize is the fact that many people with very meager mathematical training and still less ability are wasting their time and money by working out and publishing supposed proofs. The number of these is already much beyond 1,000 and no one can foresee the extent to which this kind of literature will grow, especially if the complete solution will not be attained during the century. A great part of this waste would be eliminated if those who would like to test their ability along this line could be induced to read, before they offer their work for publication, the discussion of more than 100 supposed proofs whose errors are pointed out in a German mathematical magazine called *Archiv der Mathematik und Physik*, published by B. G. Teubner, of Leipzig. A very useful pamphlet dealing with this question is entitled, "Ueber das letzte Fermatische Theorem, von B. Lind," and was also published by B. G. Teubner, in 1910.

While it is very desirable to be familiar with such standing problems as Fermat's theorem, they should generally be used by the young investigator as an indirect rather than as a direct object of research. Unity of purpose can probably not be secured in any better way than by keeping in close touch with the masters of the past,[8] and this unity of purpose is almost essential to secure real effective work in the immense field of mathematical endeavor. As a class of problems which are much more suitable for direct objects of research on the part of those who are not in close contact with a master in his field, we may mention the numerous prize subjects which are announced from year to year by foreign academies.

Among the learned societies which announce such subjects the Paris Academy of Sciences is probably most widely known, but there are many others of note. The subjects announced annually by these societies cover a wide range of mathematical interests, but they are frequently beyond the reach of the young investigator.[9] It is very easy to obtain these subjects, since they generally appear in the "notes" of many mathematical journals. In our country the *Bulletin of the American Mathematical Society* is rendering very useful service along this and many other lines. While some of these subjects are very general, there are others which indicate clearly the particular difficulties which must be overcome before further progress in certain directions seems possible and hence these subjects deserve careful study, especially on the part of the younger investigators.

As long as one is completely guided, in selecting subjects for research, by the standing problems or by the subjects announced by learned bodies and those proposed individually by prominent investigators, one is on safe ground. Real progress along any of these lines is welcomed by our best journals, as such progress can easily be measured, and it fits into a general trend of thought which is easily accessible in view of the many developed avenues of approach. Notwithstanding these advantages, the real investigator should reach the time when he can select his own problems without advice or authority; when he feels free to look at the whole situation from a higher point of view and to assume the responsibility of an independent choice, irrespective of the fact that an independent choice may entail distrust and misgivings on the part of many who would have supported him nobly if he had remained on their plane.

In looking at the whole situation from this higher point of view many new and perplexing questions confront us. Why should the developments of the past have followed certain routes? What is the probability that the development of the territory lying between two such routes will exhibit new points of contact and greater unity in the whole development? What should be some guiding principles in selecting one rather than another subject of investigation? What explanation can we give for the fact that some regions bear evidences of great activity in the past but are now practically deserted, while others maintained or increased their relative popularity through all times?

While there has been a very rapid spread of mathematical activity during recent years, it must be admitted that the greater part of the work which is being done in the new centers is quite elementary from the standpoint of research. The city of Paris continues to hold its preeminent mathematical position among the cities of the world; and Germany, France and Italy continue to lead all other countries in regard to the quality and the quantity of research in pure mathematics.

Although America is not yet doing her share of mathematical research of a high order, we have undoubtedly reached a position of respectability along this line, and it should be easier to make further progress. Moreover, our material facilities are increasing relatively more rapidly than those of the countries which are ahead of us, and hence many of our younger men start under very favorable conditions. Unfortunately, there is not yet among us a sufficiently high appreciation of scholarly attainments and scientific distinction. The honest and outspoken investigator is not always encouraged as he ought to be and the best positions do not always seek the best man. I coupled outspoken with investigator advisedly, since research of high order implies liberty and scorns shams, especially shams relating to scholarship. Even along these lines there seems to be encouraging progress, and this progress may reasonably be expected to increase with the passing of those who belong to the past in spirit and attainments. What appears to be a very serious element in our situation is the fact that the American university professor does not yet seek and safeguard his freedom with the zeal of his European colleague. It is too commonly assumed that loyalty implies lying.

The investigators in pure mathematics form a small army of about two thousand men and a few women.[10] The question naturally arises what is this little army trying to accomplish. A direct answer is that they are trying to find and to construct paths and roads of thought, which connect with or belong to a network of thought roads commonly known as mathematics. Some are engaged in constructing trails through what appears an almost impassable region, while others are widening and smoothing roads which have been traveled for centuries. There are others who are engaged in driving piles in the hope of securing a solid foundation through regions where quicksand and mire have combined to obstruct progress.

A characteristic property of mathematics is that by means of certain postulates its thought roads have been proved to be safe and they always lead to some prominent objective points. Hence they primarily serve to economize thought. The number of objects of mathematical thought is infinite, and these roads enable a finite mind to secure an intellectual penetration into some parts of this infinitude of objects. It should also be observed that mathematics consists of a *connected* network of thought roads, and mathematical progress means that other such connected or connecting roads are being estab-

[4] This view was expressed earlier by Kronecker, who was the main founder of the school of mathematicians who aim to make the concept of the positive integers the only foundation of mathematics. Cf. Klein und Schimmack, "Der mathematische Unterricht an den hoecheren Schulen," 1907, p. 175.

[5] Bôcher discussed some of the proposed definitions in the *Bulletin* of the American Mathematical Society, vol. ii. (1904), p. 115.

[6] Lietzmann, "Der Pythagoreische Lehrsatz," 1912, p. 52.

[7] Fermat's words are as follows: "Cujus rei demonstrationem mirabilem sane detexi. Hanc marginis exiguitas non caperet."

[8] Darboux, *Bulletin des Sciences Mathématiques*, vol. xxxii. (1908), p. 107.

[9] For solutions of such problems in pure mathematics by Americans, see *Bulletin* of the American Mathematical Society, vol vii. (1901), p. 190; vol. xvi. (1910), p. 267.

[10] Between five and ten per cent of the members of the American Mathematical Society are women, but the per cent of women in the leading foreign mathematical societies is much smaller. Less than one per cent of the members of the national mathematical societies of France, Germany and Spain are women, according to recent lists of members. The per cent of important mathematical contributions by women does not appear to be larger, as a rule, than that of their representation in the leading societies. The list of about three hundred collaborators on the great new German and French mathematical encyclopedias does not seem to include any woman. Possibly women do not prize sufficiently intellectual freedom to become good mathematical investigators. Some of them exhibit excellent ability as mathematical students.

lished, which either lead to new objective points of interest or exhibit new connections between known roads.

The network of thought roads called mathematics furnishes a very interesting chapter in the intellectual history of the world, and in recent years an increasing number of investigators have entered the field of mathematical history. The results are very encouraging. In fact, there are very few other parts of mathematics where the progress during the last twenty years has been as great as in this history. This progress is partly reflected by special courses in this subject in the leading universities of the world. While the earliest such course seems to have been given only about forty years ago, a considerable number of universities are now offering regular courses in this subject, and these courses have the great advantage that they establish another point of helpful contact between mathematics and other fields.

Mathematical thought roads may be distinguished by the facts that by means of certain assumptions they have been *proved* to lead safely to certain objective points of interest, and each of them connects, at least in one point, with a network of other such roads which were called mathematics, *μαθήματα* by the ancient Greeks. The mathematical investigator of the present day is pushing these thought roads into domains which were totally unknown to the older mathematicians. Whether it will ever be possible to penetrate all scientific knowledge in this way and thus to unify all the advanced scientific subjects of study under the general term of mathematics, as was the case with the ancient Greeks,[11] is a question of deep interest.

The scientific world has devoted much attention to the collection and the classification of facts relative to material things, and has secured already an immensely valuable store of such knowledge. As the number of these facts increases, stronger and stronger means of intellectual penetration are needed. In many cases mathematics has already provided such means in a large measure; and, judging from the past, one may reasonably expect that the demand for such means will continue to increase as long as scientific knowledge continues to grow. On the other hand, the domain of logic has been widely extended through the work of Russell, Poincare and others; and Russell's conclusion that any false proposition implies all other propositions whether true or false is of great general interest.

While the mathematical investigator is generally so engrossed by the immediate objects in view that he seldom finds time to think of his services to humanity as a whole, yet such thoughts naturally come to him more or less frequently, especially since his direct objects of research seldom are well suited for subjects of general conversation. If these thoughts do come to him they should bring with them great inspiration. Who can estimate the amount of good mathematics has done and is doing now? If all knowledge of mathematics could suddenly be taken away from us there would be a state of chaos, and if all those things whose development depended upon mathematical principles could be removed, our lives and thoughts would be pauperized immeasurably. This removal would sweep away not only our modern houses and bridges; our commerce and landmarks, but also most of our concepts of the physical universe.

Some may be tempted to say that the useful parts of mathematics are very elementary and have little contact with modern research. In answer we may observe that it is very questionable whether the ratio of the developed mathematics to that which is finding direct application to things which relate to material advantages is greater now than it was at the time of the ancient Greeks. The last two centuries have witnessed a wonderful advance in the pure mathematics which is commonly used.[12] While the advance in the extent of the developed fields has also been rapid, it has probably not been relatively more rapid. Hence the mathematical investigator of to-day can pursue his work with the greatest confidence as regards his services to the general uplift both in thought and in material betterment of the human race. All of his real advances may reasonably be expected to be enduring elements of a structure whose permanence is even more assured than that of granite pillars.

[11]The term mathematics was first used with its present restricted meaning by the Peripatetic School. Cantor, "Vorlesungen über Geschichte der Mathematik," Vol. I. (1907), p. 216.

[12]In 1726, arithmetic and geometry were studied during the senior year in Harvard College. Natural philosophy and physics were still taught before arithmetic and geometry. Cajori, "The Teaching and History of Mathematics in the United States," 1890, p. 22.

Mushrooms as Cheap Food*

THE increased cost of living! Everybody bewails it. Meat, eggs, milk, sugar, flour, every article by which life can be sustained is being pushed up, until people are paying "all the traffic will bear;" and still the greed of suppliers is unsated.

Men begin to calculate diet tables, to measure the nutritive values of food against wages, to think less of sapids and more of calories. Life grows harder, the struggle for existence sterner as the earth becomes crowded.

Meanwhile bounteous nature spreads for us, in every forest dell, on every lawn and pasture field a wealth of wholesome and delicious viands which we pass by unnoting or crush under our heel ruthlessly. Of the six thousand fungi of the United States, three are poisonous, further three unwholesome, but the larger number of the rest afford as appetizing and nutritious food as man could ask. In the shops, cultivated mushrooms bring from fifty cents to a dollar a pound. Many of the wild ones are finer flavored, and are to be had for the gathering. In the city of Chicago alone fifty thousand persons could dine daily on this food for the gourmand without exhausting the supply to be gathered within the municipal limits. Ignorance is costly!

In New York city it is reported that thirty persons have died this summer from eating poisonous mushrooms, gathered with the wholesome varieties.

Truly, ignorance is costly!

Six bad varieties of the mushroom family prevent the utilization of six thousand good ones—and yet, it is easy to distinguish the poisonous kinds, nor difficult to identify the others. The trouble is that the works treating of the fungi are rare and costly, hence not to be found outside of libraries.

Here is a field for public intervention, and some of the States have recognized this. The State of New York has published a volume, beautifully illustrated, describing the fungi found growing within its territory. Mr. T. C. Clements, State Botanist of Minnesota, has issued the fourth volume of "Minnesota Plant Studies," which deals with the mushrooms of that State. He describes over three hundred varieties. The three deadly amanitas (phalloid, vernal, and fly) are figured and described, so that they could not fail to be recognized by any person of average intelligence. Several others are listed as unwholesome, others as doubtful, many as unfit for food for various reasons, or untried; but a surprising number are pronounced "edible," "excellent," or "delicious." A chapter is added on the manner of collection, together with various methods of cooking the different edible sorts. Any family possessing and utilizing this book may have, for the slight trouble of collecting, a daily meal of this, one of the costliest dishes set before the epicure.

If you like mushrooms or feel willing to enjoy a wholesome delectable dish for the trouble of picking it up, get a book on fungi like the one named. Gather all the mushrooms you find, putting each variety in a separate paper bag. Do not take any old ones, but be sure to dig out the whole stem, so that the variety may be recognized.

The three poisonous fungi are all amanitas. These have a centrally inserted stem, the top separating readily; around the stem is a ring or collar, and the base of the stem is bulbous and surrounded by a volva, or onion-like scaly sheath. Place a ripe specimen on a sheet of colored or black paper and shake it, when the spores falling out are seen to be white. Other wholesome mushrooms have the ring or the volva, but no others have both and also the white spores, as is true of the three deadly amanitas.

The amanita phalloides, or death-cup, is 1½ x 4 inches wide, white (rarely olive, brown, or yellow), shiny when moist, smooth or rough with fragments of the volva; stem, 3 to 6 inches long, 1/3 to 1/2 inch thick, white, rarely dark, smooth, bulbous, and hollow above the ring close to the cap. The volva may be overlooked if covered with dirt. The deadly amanita grows in the woods from June till October. It contains two poisons, phallin and muscarine.

Phallin is a hemolysin, causing solution of the blood-corpuscles, like snake venoms. It is destroyed by cooking it thoroughly. There is no known antidote, although recent observations indicate that arsenic has some anti-hemolytic power.

Muscarine is an alkaloid that causes sweating, purging and vomiting, with depression. It is antidoted completely by atropine. If one eats only cooked mushrooms he is safe from phallin, and cannot die from muscarine if he takes enough atropine to keep his mouth dry.

The amanita verna is a variety of the phalloid, and equally deadly.

The amanita muscaria, or fly-cap, is 4 to 6 inches wide, bright-red, or orange, yellow or whitish when old; the top is rough with corky fragments of the volva, which in the early form envelops the whole plant. These fragments may disappear as the fungus ages. The margin is striate, the stem thick, 3 to 6 inches long, white, scaly, bulbous, hollow, the ring large, the volva forming concentric scaly rings on the bulb. It grows in the woods and clearings till frost. It contains only muscarine—no phallin—hence can be antidoted by atropine.

These are the three deadly mushrooms, or so-called "toadstools." Learn to recognize them, even in forms varying from the typical dimensions, but with the ring, volva, and white spores—the three characteristics of the amanitas.

Of the others, Clements pronounces 125 varieties edible, 54 excellent, 24 delicious, 16 doubtful, 10 distasteful, 3 unwholesome, 1 pleasant, and 21 not tested.

Surely, such a wealth of food-resources should not be allowed to go to waste. There is no danger so long as one adheres to the one safe rule of eating no fungus until he has first identified it botanically.

However, to know that a given mushroom is not one of the three deadly amanitas is not enough, since several others are poisonous to some persons. *Old, decayed, wormy mushrooms or those gathered the day before may be unwholesome.* Many varieties are only of value when quite young, as the puff-balls, which should not be eaten after they turn yellow and wrinkle.

The most common mushroom of the Chicago lawns is the hypholoma. It is exceedingly fragile, and decays before its first day of life has ended. It is wholesome, nutritious, and of pleasant flavor, some would say "excellent," but hardly "delicious." The writer and his family use it as any other vegetable, and have consumed bushels of it. The horse-tail coprinus (*coprinus comatus*) is sometimes found, and fully merits the term delicious. The russulas seem to be doubtful, being unwholesome at some seasons, to some persons or under some conditions, but not under others. An enormous mushroom, as large as a dinner plate and weighing several pounds, did not answer the description of any variety listed, but proved to be poisonous—probably a fly-amanita.

* Reprinted from the *American Journal of Clinical Medicine.*

Color Photography

THE new Krayn color plates for photography which are appearing in Europe are based on a somewhat unusual process. As before, different colors are applied in a network upon the plate. Such colors are printed on the gelatine by dipping it in several dye baths, red, blue and green, but keeping back various parts of the surface in each case by applying fatty inks. First, the fatty inks are printed on in the places which the blue and violet are to afterward occupy, so as to prevent the red or first bath from dyeing these parts. After dyeing the red and fixing this color, the next step is to dye with blue. To do this, all the fatty ink is removed by turpentine, ink is once more applied, but now only in the parts which the green is to occupy. This leaves clear the places reserved for the blue, which are now dyed, and then the fatty ink is again removed so as to expose the part to be dyed green. The colors are put on in parallel crossed lines so as to form small squares of color, and one square inch contains 150,000 color elements. The gelatine is then coated with emulsion as usual.

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TABLE OF CONTENTS

PAGE

Experimental Evidence Concerning the Structure of the Atom.—By Albert W. Hull 386
Blast Furnace Slag and Its Applications 387
Life Phenomena Obeying the Laws of Chemical Action 387
The "Salandia"—4 illustrations 388
Model of a Furnace House.—1 illustration 389
The United States Patent System.—II.—By Robert M. Kenyon 390
Scientific Management from a Social and Economic Standpoint 391
The Pressure of a Blow.—II.—By Prof. Bertram Hopkinson.—9 illustrations 393
On the Trail of the Subconscious.—By Prof. Joseph Jastrow 394
The Gaumont Speaking Kinematograph Films 395
Adhesive for Sail Cloth 395
The Theory of Welding Steel and Its Practical Application.—By Max Bermann.—14 illustrations 396
Modern Mathematical Research.—By Prof. G. A. Miller 398
Mushrooms as Cheap Food 400

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10 dis-
tested.
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AGE
386
387
387
388
389
390
391
393
394
395
395
396
398
406